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THE CONTROL OF FISH PREDATORS AT HATCHERIES AND REARING STATIONS[1]

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At various times during the past eight years, studies of vertebrate predation on fishes have been carried on in Michigan. An important phase of the work has been an investigation into methods and effects of controlling fish predators at hatcheries and rearing stations, and an evaluation of the effects of such control. One aim has been to find means of reducing expensive losses of fish, and of man-hours required for the most commonly practiced forms of control—shooting and trapping. The work has been conducted in the hope that it might lead to greater economy and efficiency in fish culture, by methods which will conserve the lives of countless fish-eating animals. Attempts have been made to find effective and practicable means of control which, wherever possible, do not involve killing.

In order to augment my experimental data and observations obtained during the past two years in Michigan, 390 questionnaires were sent to hatcheries throughout the United States. These inquiries were designed to bring together recent developments in methods of control of predation on fishes, to gather information on the present status of predator control at fish hatcheries and rearing stations, to enumerate the kill, and to summarize the views of hatchery officials on the predator problem. The questionnaires were sent out under the direct auspices of the Institute for Fisheries Research at the suggestion of A. S. Hazzard. The American Wildlife Institute and the University of Michigan cooperated.

Richard H. Pough of the National Association of Audubon Societies assisted in drafting the questions and contributed information which he had gathered on this problem in 1936. The U. S. Bureau of Fisheries, through the kindness of M. C. James, assumed the task of mailing the blanks to federal hatcheries. The invaluable counsel and guidance of Carl L. Hubbs were continually available, and Milton B. Trautman gave important technical advice. The kind cooperation of these and all other coactive agencies and individuals is hereby gratefully acknowledged.

Of the questionnaires sent out, eighty went to federal, three hundred to state, and ten to private hatcheries. Returns number 241, including thirteen which

[1] Contribution from the Cooperative Fish Management Unit, sponsored by the American Wildlife Institute with support from the Associated Fishing Tackle Manufacturers, the Institute for Fisheries Research of the Michigan Department of Conservation, and the University of Michigan.

are not treated in the following summary because they represent stations which are entirely under roof or for some other reason have no problems directly dealing with fish-eating animals.

In the 228 hatchery units of thirty-eight states, the replies of which are analyzed, there are according to the reports approximately 135,714 linear feet of raceways, and 2,861 ponds with a total area of 2,223 acres. In these waters more than thirty[2] kinds of fish are cultured. At 110 stations predation is regarded as involving significant losses and as a menace to the economical operation of the plant, whereas at 112 establishments predation is not considered a problem. Whether or not predation is regarded as a serious problem, the men in charge of many stations consider current control methods (mostly trapping and shooting) inadequate, from either the point of view of holding down losses of fish or of convenience.

A few hatcheries estimate that the value of fish annually taken by vertebrate predators may be as much as one thousand dollars.[3] Percentages of fish lost from single ponds have been as great as one hundred per cent.

The experience of these fish culturists is presented that it may contribute to understanding and solution of the problem of predator control at fish hatcheries and rearing establishments. Details of experiments on predator control in Michigan will be reported in other papers. No data are here included on analyses of the feeding habits of predatory animals at fish stations, or on interpretations of the complex effects of predation in these environments of concentrated prey.

CONTROL METHODS WHICH FRIGHTEN AWAY OR EXCLUDE PREDATORY ANIMALS

SCREENS

Covering screens. Covering screens are recorded as used for the exclusion of fish-eating birds and other animals at twenty-four stations. Included in the variety of screening devices in current use are: tar paper and wood slat covers for raceways; rotary screens driven by water power on circular ponds; cloth screens claimed to reduce algal growth and to exclude not only fish-eating birds but also other fish-eating animals from raceways and small circular ponds; and poultry-wire screens on frames or in large rolls for covering raceways or small ponds.

In all installations reported, covering screens are stated to be effective in the exclusion of fish-eating birds and frequently of certain mammals, snakes, and turtles.

A disadvantage in the use of screening is its interference with the handling of the fish, as in feeding or cleaning operations. Since this type of protection is limited in its application to small ponds, raceways, and rearing troughs, the interference with routine duties should be reduced to insignificance if convenience along with effectiveness is kept in mind when the construction is planned. Ultimately, fewer hours will be spent in the control of predators when such a contrivance is in opera-

[2] Swepson, Earle. "Fish culture is big business in the United States," *The Progressive Fish Culturist*, No. 41, 1937.

[3] From the unpublished data of Richard H. Pough gathered during 1936.

tion than are necessary for the shotgun patrol or for staking out and tending steel traps.

Marginal fences. The federal hatchery at Saratoga, Wyoming, and some New Hampshire hatcheries employ a poultry-wire fence about twenty-four inches high at the water's edge about raceways and ponds. Since wading birds do not ordinarily alight in water, this fence, it is thought, materially retards such birds from destroying fish.

Double-end box traps or ground pits installed at intervals along such a fence will capture turtles and snakes.

At another station similar advantage in the exclusion of wading birds is claimed for a two-strand wire fence placed in the same way as the poultry fence just cited.

Field observations indicate that such fences may not entirely exclude wading birds. Great blue herons have often been seen to alight directly on water several feet deep and while floating there to capture injured fish liberated from fishermens' hooks. Somewhat rarely, they have been observed to catch fish by diving, kingfisher fashion, from a height of about twenty feet. Might not these adaptable habits enable the birds at least occasionally to obtain fish from fenced fish-rearing waters?

WIRES

Wires strung above the water to exclude fish-eating birds or to frighten them away have been reported as tried at seventeen stations. Experience has indicated that the proper type of wiring to be used depends on the size and location of the body of water to be protected and on the bird species to be excluded.

Cross-wiring near water level. For raceways, nine- to sixteen-gauge wires strung in eight-inch squares on wooden frames and placed about two feet above the water were found by Guy Lincoln at Oden, Michigan, to eliminate predation by such birds as kingfishers, mergansers, and herons. A disadvantage of such a covering is that it tends to become unsightly and malodorous when feeding operations are carried on without the removal of the frames. The use of light-gauge wire will partially obviate this difficulty. To permit cleaning operations or removal of fish, the frames can be readily propped up at one side.

For small ponds, a half acre or less in area, wires strung to form twenty-four-inch squares about two feet above the water are regarded as likely to exclude birds which alight upon the water but the maximum effective size of mesh still needs to be determined by extensive trials. It may be expected that herons will feed about the margins of a pond so treated and that occasionally a kingfisher will fish through the mesh. Since kingfishers have been observed to perch on nine-gauge wire, it is recommended that lighter wire be used where possible. Whether more time would be consumed in removing and reinstalling the wires each time a pond so covered is cleaned or seined than would be required in the usual shotgun patrol, is difficult to predict. It is certain that to save fish lives and bird lives simultaneously is good conservation.

For larger ponds, of one or several acres in surface area, wiring is generally deemed impracticable. The construction and maintenance of this type of

protective measure over large areas would seem to be too costly and inconvenient to be justified by the losses in fish which might be prevented. Howard S. Doyle of Nevada, however, records having tested and found effective lightweight telephone wire strung in twenty-four-inch parallels about two feet above the water on a two-acre pond. According to observations made at this Nevada station, great blue herons are usually frightened by the wires. An occasional over-bold individual is killed while attempting to rise under the wires.

Overhead wiring. Where predation by birds is extremely severe, overhead wiring[4] may be practicable, especially in raceways and small ponds of northern trout-rearing establishments where losses of fish to birds continue throughout the year. Arches of iron pipe or other types of frames erected to support the wires should be made sufficiently strong to withstand extreme conditions of ice and snow. Sixteen-gauge wire of a non-rusting material, preferably steel-core copper wire, is suggested. From a preliminary experiment,[5] it is believed that the wires will need be six inches apart and parallel to the length of the reaceways to afford protection. The use of second-hand piping and Civilian Conservation Corps labor considerably reduces the cost for this type of protection. There are advantages of overhead wiring; once erected there is no need to move parts to enable handling of fish, and maintenance costs are negligible.

WIND-OPERATED SCARES

The sole wind-scare on which the questionnaires give definite information consists of tin cans bunched and tied to wires and exposed to wind for noise making. The federal station at Dexter, New Mexico, which tested this contrivance, reports it to be unsuccessful.

By using pendent, shiny squares of tin and rotating beams of light F. M Uhler and S. Creech of the Bureau of Biological Survey have been successful in frightening ducks and geese from a grain field near Unionville, Michigan. "In the approximate center of the field they placed an iron pole in the ground. At the top [about four feet above the ground] they set an ordinary bicycle wheel, atop which they placed two electric lanterns. On the underside they attached six curved tins so that the slightest stir of wind would revolve the wheel and lanterns."[6] As the wheel rotates, the beams of light are reflected from squares of tin suspended from cross arms of stakes placed at intervals over the whole field. "Apparently terrified by the flickering tins, not a duck has set foot in the field since the... [device] was set up."[6] Although this system has not been tested for its effect on the behavior of fish-eating birds, its apparent possibilities for frightening these birds warrants its mention here.

[4] McAtee, W. L. and S. E. Piper. "Excluding birds from reservoirs and fish ponds," *U. S. Dept. Agric., Leaflet*, 120, Sept. 1936, 6 pp.

[5] Conducted during 1937 in cooperation with Donald V. Gray of the U. S. Forest Service at East Tawas, Michigan.

[6] Wood, Robert B. "Strange gadget frightens ducks," *Ann Arbor News* (Ann Arbor, Michigan), Saturday, October 29, 1938:9.

Specific information is lacking on noisy windmills, wind-animated scarecrows, and "scarebirds"[7] as suggested by Cottam and Uhler.

MECHANICAL NOISE-MAKING DEVICES

Automatic acetylene detonator. Brief tests were conducted during the past summer on the automatic acetylene detonator (or flash "gun") sold by the Salt Lake Stamp Company, Salt Lake City, Utah. This detonator generates acetylene gas as water drips on calcium carbide through an adjustable valve from a reservoir. At controlled intervals a report occurs, which resembles that of a twelve-gauge shotgun. Simultaneously with the explosion the gun takes on a sudden movement and a blue-white flame about two feet in length is emitted from the firing chamber. The machine operates continuously and automatically through functioning of a pilot light. A single filling of calcium carbide will last as long as twenty-four hours, exploding at intervals of two minutes. A twenty-four-hour charge of carbide costs about ten cents, and about ten minutes of time is required for a man to clean and refill the "gun" each day.

During five days and nights of full-time operation of the detonator suspended above a quarter-acre group of trout raceways and small rearing ponds, two kingfishers, two American bitterns, and one great blue heron were seen to fish in close range of the exploding "gun." It cannot be stated how many birds were prevented from feeding on the fish during the period of the test. Judging from the flashing of this "mechanical scarecrow" at night, it has definite possibilities in the control of night herons, and others of the heron tribe. A combination of this device with pendent, shiny squares of tin is doubtless worth testing. (The detonator has proved effective in the control of blackbirds, robins, and starlings about cherry orchards in southern Michigan.[8])

Firearms. Two stations report successful use of firearms as frightening devices.

Other noise-making devices. Marine sirens, klaxons, and loud gongs electrically timed and operated are not known to have been examined for their possibilities.

MISCELLANEOUS METHODS

At Marion, Alabama, it has been found that since even one martin can drive any osprey off the grounds, boxes put up on poles for martin nests are a distinct asset.

Scarecrows on pond walls are reported as effective at the Springville, Utah, federal hatchery, but as useless at the Leetown, West Virginia, station. A floating scarecrow, however, was estimated to be 80 per cent effective on circular ponds at the Bear Lake federal hatchery, Utah. "Kingfishers became more bold and less afraid of this scarecrow than any other predator."

Interest in live trapping, banding, and removing birds to other territories was expressed by C. L. Edmundson, a federal fish culturist of Smokemont,

[7] Cottam, Clarence, and F. M. Uhler. "Birds in relation to fishes," *U. S. Dept. Agric., Wildlife Research and Management Leaflet*, BS-83, May, 1937, 16 pp.

[8] Cardinell, H. A. "Protecting cherries from birds," *Mich. St. Coll., Agric. Exp. Sta. Circ. Bull.* 160, May, 1937, 22 pp.

North Carolina. "Verbail" live pole-traps for kingfishers were tried at a few stations in Michigan during the past summer. Despite all possible care taken to set traps so that the lightest contact (by a bird) would release the mechanism, no birds were caught during a trial period of three months, although birds were caught in adjacent steel pole-traps. A successful method of live trapping would be welcome.

A rather novel live trap for great blue herons and American bitterns is suggested by A. P. Fleury of Hollis, Maine, who writes:

"I found a very successful way in trapping Blue Herons [*Ardea herodias*] and Marsh hens [*Botaurus lentiginosus*]. It is as follows: take a flour barrel and break out both top and bottom; cut barrel so it stands out of the water about one and one half feet and paint this portion a dull gray or black.

"This barrel is stood up on end in the center of ponds or pools. Cover top with wrapping paper and take a razor blade and cut slits the whole width of the barrel top. Herons and marsh hens take this for a stump or something to light upon . . . and break through the paper that is already weakened by cutting. After the bird goes through the paper it is in the water and since it has no room for its wings to open, it is unable to rise from the barrel trap."

Fleury also reports that a well-trained hunting dog frightens animals away from his trout raceways and rearing ponds.

Table-like covers placed in small rearing ponds to afford shade for fish, may also be made to furnish protection from predators according to Russell Lord of Pittsford, Vermont. Since ordinarily these covers provide excellent places upon which wading birds may alight and from which they may successfully fish, Lord is placing poultry netting screen about the edges of his covers in order that birds cannot stand at the edge and strike.

The hanging of dead fish-eating birds on poles about ponds, suggested in the replies on one questionnaire, is undoubtedly ineffective and gruesome.

The electric fence as a means of controlling wading birds and electrified shocking perches for kingfishers, grackles, and other birds, is apparently untested.

Carl L. Hubbs reports that he has seen pendent, shiny squares of tin successfully used to protect Japanese rice fields from bird depredations. The squares are suspended from ropes which radiate from a control stand in the center of the field. Impulses from there cause all the squares to move and reflect the sun in many flashes.

ENVIRONMENTAL CONTROL

It is well known that great concentrations of available prey result in "baiting" predators. Fish hatcheries and rearing stations with their high populations of fish are very attractive in this way. Since such concentration is unavoidable in fish culture, all environmental features which aid predators should be eliminated so far as possible.

Location of hatcheries. Severe predation may often be prevented by locating fish-cultural establishments outside the usual limits of the major flyways of fish-eating birds and beyond the flight range of large nesting colonies. In Michigan it has been found that stations located on or near the shores of

the upper Great Lakes are visited by many more kingfishers than comparable stations farther inland.

Pond construction. In the construction of rearing ponds, the shoreline should be as regular as possible, since irregularity often aids predation.

In ponds and raceways with concrete or rip-rap vertical walls, and with the water level two feet below the top of the wall, the fish are much less vulnerable to predation than in ponds with gradually sloping sides. It seems desirable to have at least eighteen inches of water at the margins of ponds and raceways. A. H. Dinsmore of Berlin, New Hampshire, reports this type of construction effective.

Fish concentrations. The more concentrated the fish in a body of water or in a part of it, the greater is their vulnerability to predation. Any device or practice which will ensure even distribution of fish in rearing enclosures rather than encourage concentrations, at such points as water inlets, for example, lowers their vulnerability to predation (and to disease).

Marginal vegetation. Frequent trimming of weeds about the margins of ponds and raceways creates a less favorable environment for snakes and other predatory animals.

Removal of fishing perches. Elimination of perches for kingfishers may reduce predation to a certain extent, but cannot be expected to eliminate it entirely. Kingfishers can successfully fish without the aid of perches.

Buffer populations. In 1935, Indiana conservationists, recognizing the important position of frogs and toads in the diet of fish-eating birds and other piscivorous animals, mentioned the possibility of creating amphibian buffer populations.[9] The proposal was to surround fish ponds with several pools and to stock these with breeder frogs and toads. Although this plan is not without merit, it has apparently never been tested. An abundance of forage fish might also serve to lessen the loss of game fish.

Several buffer organisms ordinarily occur in or about most rearing ponds, particularly those in use for pond-fish culture. Many of these organisms are either enemies of fish or harm the pond structure. Moles, snakes, tiger salamanders, crawfish, and giant water bugs, diving beetles, and other predacious insects are among them. Most of these forms often appear in the stomachs of larger fish-eating animals.

CONTROL METHODS WHICH INVOLVE KILLING

POLE-TRAPS

Ninety hatcheries report the use of at least 514 pole-traps; the number in use at any particular station ranges from one to fifty. Ordinarily a unit consisting of a No. 0 steel trap mounted on top of a pole or post five feet above ground or water level is used. In Michigan, a pole-trap is generally fastened by its chain and sliding ring to a wire which slants from the top of the pole to an under-water position where it is made fast. When a bird is captured, the trap is knocked from the pole and both bird and trap slide under the water where the dead or dying bird is rendered inconspicuous to the visiting public.

Although efficacious in the capture of kingfishers, pole-traps also take an un-

[9] From the unpublished data of Richard H. Pough gathered during 1936.

fortunate toll of small land birds most of which are protected by law. For this reason the method which ensures the immediate plunge of a sprung trap and the quick death of its occupant is undesirable. Land birds of the size of the English sparrow have been observed to alight upon the pan of a delicately set No. 0 trap without tripping the mechanism; but blue jays and birds of similar size fare less well. However, one or both of the birds' legs are often broken and consequently there are few opportunities to liberate such unfortunates unhurt.

UNDER-WATER AND BLIND-SET STEEL TRAPS

Two hundred ninety-seven under-water or blind-set steel traps are reported as used at thirty-three stations. The size employed is No. 1½. Under-water traps are set in shallow water near the margins of ponds frequented by wading birds. Blind sets, consisting of steel traps covered with a few leaves or some loose sand, are made on the banks of ponds or pools where predatory birds habitually alight. In brood-stock ponds the under-water traps frequently catch the fish they should protect. Large fish feeding on the bottom are often caught; more frequently, however, they spring the traps without injury to themselves.

The efficiency of under-water traps has been increased at the Santa Rosa, New Mexico, federal hatchery by concentrating traps about stakes on which carp or other coarse fish have been impaled to function as lures.

TURTLE TRAPS

Turtles are considered fish predators at twenty-seven stations. Control has been demonstrated possible by several methods. Traps, trot lines, basking logs liberally equipped with large, barbed hooks, mass removal of turtles from their hibernation sites, and shooting with a small caliber rifle have been successfully used.

SNAKE CONTROL

Fifty-five fish-cultural establishments require some form of control against snakes. Generally water snakes of the genus *Natrix* have been found to be the principal offenders, but in Michigan, garter snakes (*Thamnophis sirtalis*) also have been found to be destructive to fish under hatchery conditions.

As previously mentioned, pits dug in the ground along marginal fences about rearing waters may be effective snake traps. Robert Smith of East Killingly, Connecticut, advertises for sale a water snake trap which he claims is very effective. I do not know, however, whether this trap has been tested at any fish hatchery.

Intensive and prolonged campaigns to eradicate snakes from hatcheries have shown that local populations of troublesome species may be reduced to very low levels. Since the movements of snakes are much more restricted than are those of fish-eating birds, intensive local campaigns for a year or two apparently reduce snake populations for several years. During two summers at a rearing station in central Michigan, all of the many snakes seen were killed, with the result that but few snakes were observed throughout the succeeding three seasons.

TABLE 1

THE KINDS OF ANIMALS AND NUMBER OF INDIVIDUALS OF EACH KIND REPORTED KILLED IN THE CONTROL OF FISH PREDATORS AT 228 HATCHERIES DURING 1937

Animals	Hatcheries reporting kills		Number killed
	By kind only	By number of individuals and kind	
REPTILES[1]			
Snakes. Species of water, garter, and pine snakes are included.	9	46	1,776
Turtles. Known to be included are musk, snapping, painted, geographic, and soft-shelled turtles.	8	19	698
BIRDS[2]			
Grebes[3]. Listed are horned and pied-billed grebes. Other species are doubtless represented.	2	10	178
Great blue heron	3	73	512
Blue herons,[3] cranes,[3] and herons[3]. Apparently subspecies of the great blue heron but also may include little blue heron and other heron species.	6	63	619
White herons[3]. This name may be interpreted as referring to American or snowy egrets and immature little blue heron.	2	9	246
Green heron	—	20	207
American bittern. Includes, perhaps, a few least bitterns which are sometimes taken for young of the American bittern.	—	16	282
Bitterns[3] and shitepokes[3]. Where doubt existed regarding the application of "bittern" or "shitepoke" to mean American bittern, least bittern, or green heron, the numbers given were placed in this category.	3	37	1,858
Black-crowned night heron	2	13	281
Night herons[3]. When reports made no distinction between black-crowned and yellow-crowned night herons and when specific distinctness could not be determined on the basis of known range, the numbers recorded were placed under this heading.	1	4	346
Mergansers[3]. Included here are American, hooded, and red-breasted mergansers, for the most part inseparable in the reports given.	5	25	408
Osprey. Sometimes called "fish hawks."	6	31	278
Gulls[3]. Recorded in questionnaires as gulls, and sea, Franklin's, and herring gulls.	—	10	117
Terns[3]. In some reports specified as common, black, and least terns.	—	7	662
Gulls and terns[3]. No separation of gulls and terns killed is made for purposes of record by stations in Michigan or by a few of the stations in other states.	—	21	136

TABLE 1—*Continued*

Animals	Hatcheries reporting kills		Number killed
	By kind only	By number of individuals and kind	
Kingfisher	8	166	5,568
Water ouzel	—	13	306
MAMMALS[4]			
Muskrat	—	8	101
Mink	—	15	64
Rats[3]	—	7	133
Some of these are probably Norway rat; others, muskrat.			

[1] A few alligators were taken at Lake Park, Georgia.
[2] Other species of birds and number of individuals reported killed are 1 water turkey, 4 least bitterns, 7 mallards, 2 wood ducks, 37 least sandpipers (?), 46 great horned owls, 40 magpies, 5 ravens, 33 crows, 5 robins, and 70 grackles. Additional unspecific groups of birds and numbers reported killed are 17 loons, 3 pelicans, 10 ducks, 20 snipes, 8 owls, 5 "canaries," and 125 blackbirds. Four "sand-cranes" (sandhill cranes) were killed at the Delafield, Wisconsin, State Fish Hatchery.
[3] Colloquial, or unspecific animal name quoted from the replies to the questionnaires.
[4] Five raccoons and four domestic cats are also reported taken.

SHOOTING

Of 213 fish-cultural establishments where shooting is employed as a means for reducing losses caused by fish-eating animals, nineteen report regular patrols while 183 shoot as occasion seemingly demands. Several stations consider this form of control the only effective and practicable means of protection for their particular set of conditions.

PREDATORS KILLED 1937

In the questionnaire, an attempt was made to learn the annual number of animals destroyed in protecting hatchery fish (Table 1). Unfortunately, the lack of uniformity in the use of common animal names, especially those of birds, and the inability of the average hatchery employee to identify correctly the animals killed, result in unavoidable uncertainty. Thomas Hinshaw, Division of Birds, Museum of Zoology, University of Michigan, assisted in the interpretation of the vernacular names of birds.

DISCUSSION OF THE RECORDS OF KILL

Since the kill records when first considered seem neither amazingly nor alarmingly high, it should be remarked that they probably are by no means complete. Many private fish rearing establishments and over 60 per cent of state-operated hatcheries and rearing stations are unrepresented in the questionnaire returns from which these data are drawn. Some stations were not provided with forms, and many others failed to reply.

There is a possibility that certain kill records are higher than actual kills, for some hatchery workers feel that such records are a form of employment insurance or a matter of personal pride. Such exaggerations are probably more than compensated for by the un-

recorded deaths of animals which, though wounded by shotguns or traps, escape immediate death.

Fish culture during 1937 in the United States entailed an unestimated total sacrifice of animals and a recorded extermination of 2,474 reptiles, 12,442 birds, and 307 mammals. It is a matter for consideration whether the reproductive capacity of each species is or is not sufficient to counter-balance the effects of the kill about fish hatcheries and rearing stations. It is regretted that much of the data on the questionnaires regarding the numbers and kinds of animals killed lacks specific value from want of uniformity of reports or failure to keep records. If accurate identifications of animals killed and complete records of take at hatcheries were available, the annual figures for each species might be employed as an index to abundance. A comparison of such figures from year to year might disclose important trends of population density and interesting cyclic phenomena.

SUMMARY AND CONCLUSIONS

This report contains data and observations on the fish-predator problem in thirty-eight states.

Since too many predators and non-piscivorous animals are killed (15,223 reported for 1937) and too many fish are annually destroyed by predators, a need exists for wider use of control methods that exclude or frighten away predatory animals.

Preliminary suggestions are given for the control of vertebrate predators of fishes at hatcheries and rearing stations. The possibilities of the many methods discussed should stimulate experiments.

The most successful methods of control in use are screening, wiring, shooting, and trapping. Less successful according to reports are wind-operated and mechanical "scares." Environmental control is largely unexplored but has evident potentialities.

Because of their extremely diverse nature, all hatcheries do not have the same problems of predation. Consequently a uniform policy of predator control is doubtless impracticable, at least in respect to detailed methods.

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COYOTE FOOD HABITS ON THE LAVA BEDS NATIONAL MONUMENT[1]

Richard M. Bond

The Lava Beds National Monument is an area of about 73 square miles, in Modoc and Siskiyou Counties in northeastern California, its dimensions being 7 to 8 miles east and west, and 9 to 10 miles north and south (Fig. 1). Almost the whole area is covered with rough and fissured lava. The southern portion of the monument is higher and has ponderosa pine and mountain mahogany as its most conspicuous plants. The northern part is lower, with considerable sage brush and bunchgrass, and lies in the Upper Sonoran Life Zone. The monument is bounded on the north and north-east by the Tule Lake Wildfowl Refuge, administered by the Biological Survey. The refuge is part of the drained bed of the former Tule Lake; much of it now planted to grain. When the stomachs and first series of scats on which this study is based were collected (December 1935 to May 1936), there was something over a square mile of water about 3 miles north of the north monument boundary. When the second series of scats was collected (May 1937 to January 1938), there were 3 or 4 square miles of water which came to within a few hundred yards of the east half of the north boundary and the north quarter of the east boundary.

In pursuit of its aim, to protect the wildfowl on its refuges from all harm, the Biological Survey has trapped a good many hundred flesh-eating mammals on or near the refuge in the past 5 years, and it was suggested to the Park Service that it might be advisable to "control" bobcats and coyotes on the adjacent monument, where they were known to occur and where they were believed to breed.

Unfortunately, no data were available as to the local food habits, because the stomachs of predators taken by the Biological Survey had not been saved. Therefore, in 1935, the Park Service assigned me to make a study. One hundred eighty-six scats were collected on the monument at intervals from December 22, 1935, through May 4, 1936, mostly by Don C. Fisher, Acting Custodian of the area, and 9 coyotes (*Canis latrans lestes*) and 2 bobcats (*Lynx rufus pallescens*) were trapped there in May 1936 for stomach-and-gut examinations. Other duties interfered with Mr. Fisher's continuing the collections in 1936, but he was able to resume them May 9, 1937, and continued through December 31. There were 156 scats in this second series (of which 5 were taken just off the monument).

[1] Acknowledgments are due to many who have helped with this work, particularly to: members of the Bureau of Biological Survey staff at the Tule Lake Refuge; Acting Custodian Don C. Fisher of the Lava Beds National Monument; Student Technician Elmer Aldrich and other members of the National Park Service; many members of the staff of the Museum of Vertebrate Zoology of the University of California (where the food material was identified) from whom I received invaluable material and technical assistance.

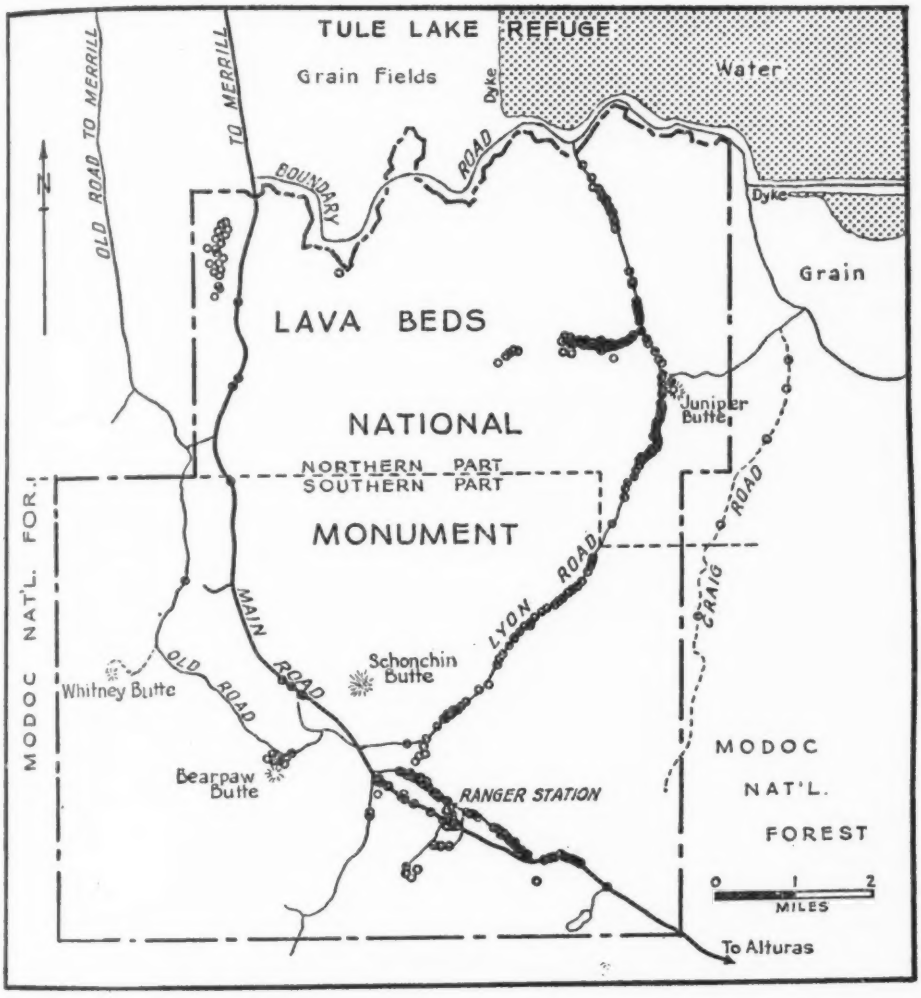

Fig. 1. Sketch map of the Lava Beds National Monument. Small circles show where scats were collected.

The identity of every scat is not certain; some may have been deposited by badgers (*Taxidea taxus neglecta*) or by bobcats. Statistically, however, scats of animals other than coyotes must be almost negligible. From tracks in the snow it would appear that the number of bobcats is only 2 or 3 per cent of the number of coyotes; moreover, the average difference in the form of the feces of the two animals, and the considerable difference in the type of locality in which they are deposited make it seem certain that little if any bobcat material was collected. Badger scats are practically indistinguishable from those of coyotes, but badgers are much rarer even than bobcats on the

TABLE 1

RECORD OF MATERIAL COLLECTED AND ANALYZED

Date			Number Collected	Number Tabulated
December,	1935	Scats	19	5
January,	1936		6	3
February,	1936		—	—
March,	1936		59	59
April,	1936		92	46
May,	1936		10	10
Totals, 1st Series			186	123
May,	1936	Stomachs	9	9
May,	1937	Scats	6	6
June,	1937		44	43
July,	1937		17	14
August,	1937		21	21
September,	1937		19	19
October,	1937		16	16
November,	1937		13	12
December,	1937		20	19
Totals, 2nd Series			156	150
TOTALS—Scats and Stomachs			351	282

monument, and during the winter months the few present are very inactive or in hibernation. All of the scats were judged to be less than two weeks old when collected, and a majority were probably three days old or less.

The first series of scats was taken wherever found on the monument. Mapping the locations showed that about 65% of them came from the southern part of the area (see Fig. 1) and 35% from the northern part. When the contents of the scats were identified, reference to the map indicated that almost all the scats were deposited within about 3 miles (at most less than 4) of the places where the food had been obtained. Therefore Mr. Fisher collected about two-thirds of the second series in the northern section of the monument, since coyotes resident in the southern part apparently seldom or never reached the area occupied by waterfowl. The stomachs all came from scattered localities in the northern two-thirds of the area.

For an estimate of the number of coyotes on the monument at various times of the year, see under "discussion" and Figure 3.

METHODS AND MATERIALS

The methods used were substantially those of O. J. Murie (1935), though greater care was taken to account for every prey organism represented, and to identify all vertebrates to subspecies, or as far as the specimens allowed.

Unfortunately, while the first collection of scats was in storage, some were attacked by molds or bacteria, and though hair and bones were little harmed, the cloth containers and some labels were destroyed. These scats were discarded as were also a few that contained no recognizable remains of food. As a result only 273 scat and 9 stomach-and-gut analyses are included in the following tabulations. The 69 undated and mixed scats contained no remains of waterfowl, and no vertebrate species not found in the other material. Dates and numbers of samples collected and analyzed are shown in Table 1.

FOOD ITEMS IDENTIFIED

It is impossible to estimate accurately how many of the mammalian food items tabulated in Table 2 represent carrion. Only horses, cattle, and a goat known to have been shot are so classified in the table, but many of the deer and some of the small mammals must have been found already dead. For further comment, see under discussion.

TABLE 2
FOOD ITEMS IDENTIFIED

TABLE 2
FOOD ITEMS IDENTIFIED

Figures in the second column (apparent number contained) obtained by the method of Murie (1935) include certain obvious inaccuracies (e.g., it certainly did not require 74 deer to give 74 scats containing deer remains; the vegetable items are recorded as 1 per scat, giving 28 gooseberries instead of the several hundred actually present). Murie's method was used, however, so as to give comparable figures in the 4th column (percentage of identifiable food items). McLean (1934) seems to have obtained his data by about the same method. Calculations for the 3d column (percentage of occurrence) are like those of Errington (1937), and similar to methods used by Sperry (1933, 1934).

Food items	No. of scats and stomachs containing this item (Total 282)	Apparent No. of individuals Contained (Total 738)		Percentage of Occurrence in scats	Apparent Percentage of countable items	
		Non-carrion	Carrion		Non-carrion	Carrion
Mammals:						
California badger (*Taxidea taxus neglecta*)	1		1	.35		.14
Domestic cat	2	2		.71	.27	
Yellow-bellied marmot (*Marmota flaviventer flaviventer*)	13	13		4.59	1.76	
Douglas ground squirrel (*Citellus beecheyi douglasii*)	1	1		.35	.14	
Oregon ground squirrel (*Citellus beldingi oregonus*)	1	2		.35	.27	
Sierra golden-mantled squirrel ? (*Citellus lateralis chrysodeirus* ?)	1	1		.35	.14	
Klamath chipmunk (*Eutamias amoenus amoenus*)	2	2		.71	.27	
Allen Chipmunk ? (*Eutamias townsendii senex* ?)	1	1		.35	.14	
Coues pocket mouse (*Perognathus parvus mollipilosus*)	19	23		6.71	3.12	
Northern California kangaroo rat (*Dipodomys heermanni californicus*)	33	38		11.66	5.15	
Desert harvest mouse (*Reithrodontomys megalotis megalotis*)	2	2		.71	.27	
White-footed mouse (*Peromyscus maniculatus gambelii* (some *P. crinitus*?))	14	18		4.95	2.44	
Dusky-footed wood rat (*Neotoma fuscipes fuscipes*)	5	5		1.76	.68	
Bushy-tailed wood rat (*Neotoma cinerea* ssp.)	2	2		.71	.27	
Peale meadow mouse (*Microtus montanus montanus*)	65	136		22.99	18.43	
Yellow-haired porcupine (*Erethizon epixanthum epixanthum*)	4	4		1.41	.54	
Unidentified small rodents	13	13		4.59	1.76	
Taylor pika (*Ochotona schisticeps taylori*)	7	7		2.46	.95	
Washington jack rabbit (*Lepus californicus wallawalla*)	24	24		8.48	3.25	
Washington cottontail (*Sylvilagus nuttallii nuttallii*)	63	68		22.25	9.21	
Rabbit (*Lepus* or *Sylvilagus*)	16	16		5.65	2.17	
Rocky Mountain mule deer (*Odocoileus hemionus hemionus*)	74	74		26.13	10.03	
Domestic sheep	18	18		6.36	2.44	
Other stock	7		7	2.46		.95
Unidentified large mammals (possibly including some marmot remains)	11	11		3.88	1.49	
Mammals total		481	8		65.18	1.08

TABLE 2—*Continued*

Food items	No. of scats and stomachs containing this item (Total 282)	Apparent No. of individuals Contained (Total 738)		Percentage of Occurrence in scats	Apparent Percentage of countable items	
		Non-carrion	Carrion		Non-carrion	Carrion
Bird's Eggs (Counted as clutches):						
Canada goose (*Branta canadensis canadensis*)	1	1		.35	.14	
Common mallard (*Anas platyrhynchos platyrhynchos*)	1	1		.35	.14	
American pintail (*Dafila acuta tzitzihoa* ?)	1	1		.35	.14	
Western meadowlark (*Sturnella neglecta*)	1	1		.35	.14	
Small passerines	2	2		.71	.27	
Pheasant (*Phasianus colchicus ssp.*)	1		1	.35		.14
Clutches, possible total		6	1		.81	.14
Birds:						
Lesser Canada goose (*Branta canadensis leucopareia*)	1		1	.35		.14
Goose ?	2		2	.71		.27
Common mallard	4	1	3	1.41	.14	.41
Gadwall (*Chaulelasmus streperus*)	1		1	.35		.14
Baldpate (*Mareca americana*)	2		2	.71		.27
American pintail?	5		5	1.76		.68
Ducks ?	6	2	4	2.12	.27	.54
Sparrow hawk (*Falco sparverius sparverius*)	1		1	.35		.14
Pheasant	3	4		1.05	.54	
Valley quail (*Lophortyx californica vallicola*)	1	1		.35	.14	
Domestic turkey	2		2	.71		.27
Wilson's phalarope (*Steganopus tricolor*)	1		1	.35		.14
Horned lark (*Otocoris alpestris merrilli*)	2	2		.71	.27	
Western meadowlark	2	2		.71	.27	
Small passerines	8	8		2.82	1.08	
Birds total		20	22		2.71	2.98
(Waterfowl, including eggs		6	19		.81	2.58

TABLE 2—*Continued*

Food items	No. of scats and stomachs containing this item (Total 282)	Apparent No. of individuals Contained (Total 738)		Percentage of Occurrence in scats	Apparent Percentage of countable items	
		Non-carrion	Carrion		Non-carrion	Carrion
Reptiles:						
Mountain swift (*Sceloporus graciosus gracilis*)	1	1		.35	.14	
Blue-bellied lizard (*Sceloporus occidentalis ?biseriatus*)	1	1		.35	.14	
Valley gopher snake (*Pituophis catenifer heermanni*)	3	3		1.05	.41	
Unidentified snakes	3	3		1.05	.41	
Reptiles total		8			1.08	
Invertebrates:						
Grasshoppers	11	134		3.88	18.16	
Crickets (*Gryllus* and *Stenopalmatus*)	6	7		2.10	.95	
Beetles (all *Carabidae* ?)	4	4		1.41	.54	
Invertebrates total		145			19.62	
Vegetable matter:						
Grass	15	15		5.29	2.03	
Apple (garbage?)	2		2	.71		.27
Wild Cherry (*Prunus emarginata* or *demissa*)	3	3		1.05	.41	
Gooseberry (*Ribes velutinum*)	28	28		9.89	3.79	
Vegetable items—total		46	2		6.22	.27
TOTALS		706	32		95.53	4.47

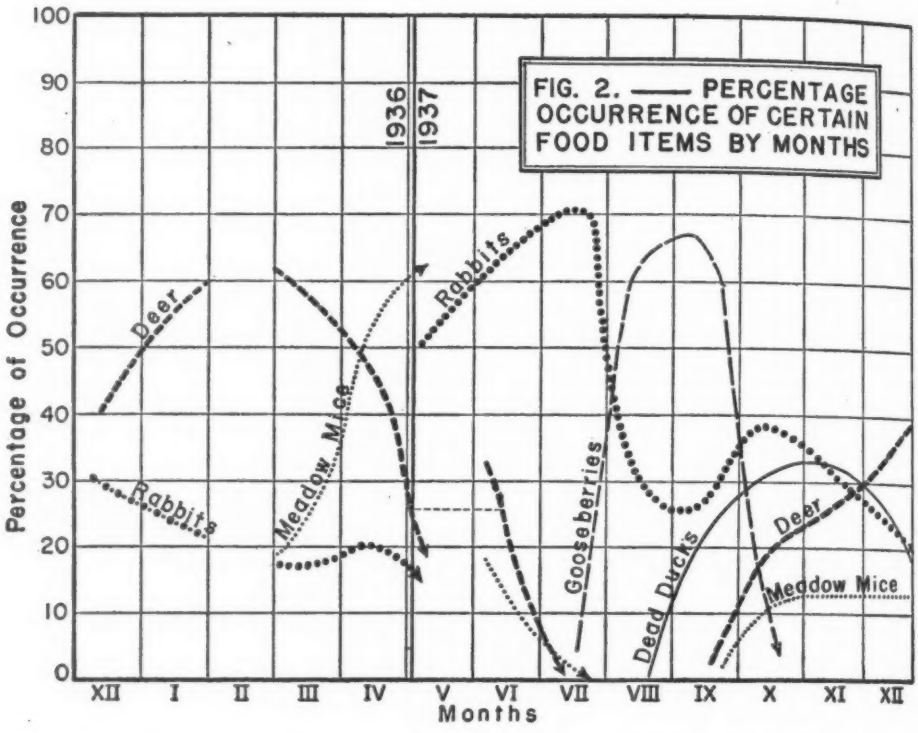

Fig. 2. Percentage of occurrence of certain food items in coyote scats from the Lava Beds National Monument.

BIRDS

Bird remains in the collection are rare and scattered except for one period. In late August 1937, botulism struck the refuge and between that time and mid-November several thousand ducks and other water birds died. Most of these washed ashore and the bodies formed a major part of the food of the local carnivores, including coyotes (which were apparently entirely or largely immune to the toxin). Before this supply became exhausted, the shooting season opened, and lost kills and cripples became available, though in decreasing numbers, as shown on the chart (Fig. 2). Since carrion and cripples eaten do not affect the duck population, they are listed separately. Also, because most birds renest when their eggs are destroyed, the eggs are listed separately. It is assumed that remains of one egg in a sample means that an entire nest of eggs has been destroyed, but this may be an overestimate.

Eggs. Canada goose? eggs in 1 scat (May 9, 1937); common mallard eggs in 1 scat (May 4, 1936); pintail? eggs in 1 scat (June 12, 1937—these fragments may possibly represent pheasant eggs rather than pintail); western meadowlark eggs in 1 scat; small birds' (at least one, probably a horned lark) eggs in 2 scats; pheasant egg in 1 scat (November 17, 1937, hence the egg

was almost certainly addled).

Birds, probably representing kills. Mallard, 1 juvenile? in 1 scat (July 1937); duck sp., a few feather fragments only, in 2 scats (May 4, 1936 and June 27, 1937); pheasant, 4 in 3 scats; valley quail?, 1 in 1 scat; horned lark, 2 in 2 scats; western meadowlark, 2 in 2 scats; small passerines definitely not waterfowl or shorebirds), 8 in 8 scats.

Birds almost certainly carrion, crippled or diseased.

See Table 2.

REPTILES

See Table 2.

INVERTEBRATES

See Table 2.

A dozen or so ticks (*Haemaphysalis leporis-palustris*) were found in scats containing mammal remains. Segments of a tapeworm were found in 1 scat, and parasitic nematodes in several of the samples. Many of the scats had one or more of the small dung beetles (*Aphodius inquinatus*) on them when they were collected, but apparently none of these beetles had been eaten by the coyotes.

VEGETABLE ITEMS

Green grass was found in 15 scats. Apple seeds occurred in 2, and chokecherries in 3. Gooseberries were a major part of the coyote diet from late July till early October. From July 27 through September 30, 1937, 46 scats were collected. Gooseberries occurred in 26 of these, comprising all of 11 and most of the bulk of 7 others. They also occurred in 2 scats collected in October.

Sticks, bark, dead leaves, hay, earth, gravel, and pebbles were encountered with surprising frequency occasionally constituting 90 per cent of a scat. Such trash made up most of the stomach contents of a majority of the trapped animals.

A chart showing the percentage-occurrence of the more important food items by months is given in Figure 2. The differences in seasonal food are well shown, as are those between the spring of 1936 and the spring of 1937, in which year the season was some two weeks late, and the numbers of *Microtus* had gone from a high to a low.

NUMBER OF COYOTES ON THE MONUMENT

From general observations at all times of the year, from the results of trapping on and near the monument, from the scarcity and abundance of scats, and from track counts made in the snow in January 1937, it is estimated that there is a hunting coyote population on the monument ranging from a low of roughly a dozen breeding pairs in early May, to something over 100 individuals in mid-winter. There is probably a second high of grown pups about August, most of which scatter and are soon destroyed, so that there may be a second low in the fall. With the first snows in the neighboring spurs of the Cascades there is a downward migration of coyotes into and through the monument. Before they have pups, many of the survivors reverse this movement, one of the reasons probably being the disappearance of water from the monument at that time. In summer the only water available is that in Tule Lake and in a very few of the ice caves on the monument. The seasonal fluctuations shown by the curve in

Fig. 3, are believed to be correct, but the numbers indicated must be considered as estimates.

It is obvious that the coyote control just outside the monument-boundaries

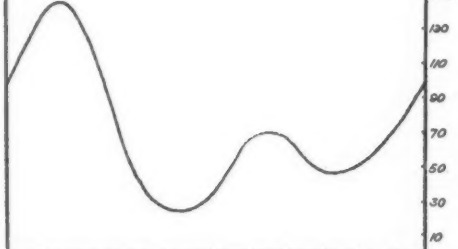

Fig. 3. Estimated number of coyotes hunting for themselves on the monument, by months.

exerts a drain on the coyote population of the area, but how much this reduces the monument-population, and how this reduction affects the food habits of the remaining coyotes, is unknown.

LIMITATIONS OF MATERIAL

The advantages of stomach analysis in food habits studies have been pointed out. Briefly they are: positive identification of species from which the stomachs are obtained; ease of measuring volumes of the various foods; somewhat more certain determination of food items; greater ease in distinguishing carrion. Against these advantages must be weighed (at least in the case of carnivores) strong drawbacks: it is virtually impossible to get a random sampling of carnivore stomachs with normal contents (cf. Murie, 1935); predators are almost always so rare that their removal to get their stomachs is likely to change the prey-predator relationship rapidly enough to alter the problem profoundly before it is solved; in local studies such as the present the total number of stomachs obtainable may be too small to give reliable figures.

Comparing stomach analysis with scat analysis, it appears (for predators, at least) that although it is possible to determine the contents of a single stomach much more accurately than that of a single scat, in investigating a limited area or a small population, study of a representative scat collection permits a more complete understanding than any practicable collection of stomachs can give. Obviously, the smaller the population, the greater the advantages of the scats over the stomachs, even though the identification of items from scats is more difficult and their succesful interpretation is liable to considerable error. Scats from one animal for a year would tell a good deal, whereas one stomach would yield data of but slight value.

A disadvantage of using scats in a food-habits study suggested by Errington (1937), results from the rate of passage of a food item through the alimentary tract. Obviously, what goes in as one meadow mouse may come out in two or three or more separate scats. In my material it was not all rare to find a scat consisting mainly of rabbit fur and bones, but including a single diagnostic element (say a cheek tooth, a humerus, or a scapula) of a meadow mouse. In such a case it seems quite clear that if the previous and subsequent scats were also in the collection, the same mouse would be counted more than once, thus giving a miscount

of food items, a wrong impression of the meaning of percentage of occurrence, and frequently a false value for the relative percentages of the different items. It is for this reason that columns 2 and 4 of Table 2 are called "apparent." In a seemingly consecutive series of scats found at a favorite coyote defecating ground, one scat consisted almost wholly of deer hair, and four others could be arranged in descending order of deer hair abundance, the last having only a very few hairs. Thus, if a deer will furnish, say, 20 meals for a coyote, and if he eats them on consecutive days, we might expect to find deer hair in 20, plus about four scats as the hair was gradually eliminated after the last meal. But, if the same deer furnished one meal for each of 20 coyotes, we should, by the same reasoning, expect to find about 100 scats with deer hair instead of 24. As a corollary it appears that if a coyote ate deer every fifth meal, all its feces might contain deer hair, so that the percentage of occurrence, though only 20 in actual meals, would be 100 in the scats. As suggested by Errington, interpretation of such instances might be improved by experimentation with captive predators, but I have had no opportunity to do this.

Some rough estimates have been arrived at, however, by comparing the numbers of scats containing most of the diagnostic elements of a given item with the numbers of those containing few such elements. This comparison would suggest that a small mammal (up to the size of a *Neotoma*) can be recognized in about 2 or 3 successive scats; a *Sylvilagus* in 3; a *Lepus* in 4; a marmot in 5; eggs in 1 or 2; a duck in 4 or 5; a pheasant in 3 or 4; small birds in 2 or 3; a snake in 3 and a lizard in 2.

It should be strongly emphasized that an array of statistics such as given in Table 2, no matter how accurately obtained (and whether presented as percentage of food by volume, percentage of food items, percentage occurrence, or by simple count), tells, directly, practically nothing about the actual, net effect of the predator on any prey-species. This is because the relative numbers of the predators and the prey, the seasonal effects, the rate of increase of the prey-species, the effects of other predatory species, and other factors all enter into the equation.

The *total coyote kill* could be obtained (at least theoretically) from figures like those in Table 2, if we knew the total coyote population, the number of scats per coyote per day and the number of scats in which each type of food item could be recognized. By more intensive field work, and observations on captive coyotes, these factors could probably be obtained to a sufficient degree of accuracy, or at least to accuracy of known degree.

To get the *net coyote effect*, however, we would need to know in addition the annual removable surplus of each prey species, and also the part the coyote plays in total predation. For a good many prey species, it would probably be more satisfactory to study the prey, its food, cover, and population tendencies, and omit direct consideration of the coyote altogether. The best practical method is to combine observations on both predator and prey, and this has been attempted in the following section.

ESTIMATION OF EFFECTS OF COYOTE PREDATION ON THE PREY SPECIES

It should be kept in mind that estimations based wholly or in part on the apparent numbers of a prey species on the monument, are complicated by predation by forms other than the coyote. No fewer than 34 other predators have been reported from the area that are known to prey on at least one warm-blooded vertebrate. Some of these are extremely abundant, at least at certain times. In the following list of predators on the monument or refuge those definitely known to take meadow mice (as an example) have been marked with an asterisk and several of the others probably do so: *rattlesnake, gopher snake, *blue heron, *American egret, Cooper's hawk, *red-tail, Swainson's hawk, *American roughleg, *ferruginous roughleg, bald eagle, golden eagle, *marsh hawk, *prairie falcon, peregrine falcon, pigeon hawk, *sparrow hawk, *California gull, *ring-billed gull, *barn owl, burrowing owl, *short-eared owl, *American raven, *northwestern shrike, *Nevada shrike, *long-tailed weasel, Pacific mink, striped skunk, badger, domestic dog, feral house cat, cougar, bobcat, and *man.

Since the coyote is large and strong, it is clear that it will have much greater proportional effect on large, strong prey than on small, vulnerable species. Thus it seems probable that coyotes kill at least half of the deer that fall to predators on the monument, because coyotes are much more numerous than the total of all other local carnivorous creatures that are ordinarily capable of killing even a fawn.

The situation with respect to smaller prey is quite different. In 1936, for example, it is certain that for every coyote that preyed on meadow mice there were at least a dozen other mammals and birds that were doing the same thing—quite possible a score or more—and some of these other predators had a very respectable capacity for meadow mice. The greatest number of meadow mice recognizable in a single coyote scat was 11, whereas a pellet of a barn owl (only about one tenth the coyote's weight) contained 9 complete skeletons. Considering this owl and other predators, it is apparent that during a meadow mouse peak, coyotes could not well be top predators on the microtines, even though they ate nothing else.

Badger. Part of the atlas of a badger was found in a scat collected September 1, 1937, just south of the center of the monument, where it could hardly have come from trap-carrion or bait. It seems most likely to have been natural carrion. In any case the effect of coyotes on badger in the area, either directly or through competition is doubtless very slight.

Domestic Cat. Remains of a white domestic cat occurred in two scats taken close together in time and place, and probably represent the same individual, though the method of preparing Table 2 makes it appear as two. Cats are found in small numbers along the north edge of the monument, especially where quail occur. They are also present in parts of the refuge, where a coot killed by one was found by Mr. Fairchild of the Biological Survey and myself in January 1937. Coyotes may possibly play some part in destroying cats.

Yellow-bellied Marmots are fairly common over most of the monument and though very inactive in winter probably appear above ground, at least in small numbers, every month in the year. Their large size introduces the likelihood that one may provide more than one meal for a coyote, which makes for difficulty in estimating from scats or stomachs the numbers actually eaten. It also means that they have few natural enemies other than coyotes, bobcats, and eagles, though the red-tailed hawks take some young.

Douglas Ground Squirrels are well distributed over the monument, though not especially abundant. In view of the findings of McLean (1934) it is perhaps remarkable that they play so minor a role in the food of coyotes.

Oregon Ground Squirrels, while common in the general region, are, on the monument, confined to a few small colonies. It appears that other predators, especially red-tailed hawks and prairie falcons, kill more of these than do coyotes.

Sierra Golden-mantled Squirrels are confined to the extreme southeastern part of the monument, whence practically no scats were obtained, so the effect of coyotes on them is unknown.

Klamath Chipmunks are numerous on the southern third of the area, and may be under considerable coyote pressure in summer. The data are too few, however, to tell.

Allen Chipmunk. A single incisor from a scat found in the spring of 1936 is referred rather doubtfully to this form, since no other specimens or sight records are known from the monument.

Coues Pocket Mouse has been trapped on the monument only by the Misses Alexander and Kellogg in 1935. About 200 trap nights by Joseph S. Dixon, Elmer Aldrich, and myself at various times in 1936 and 1937 yielded no specimens, and I have never seen one at night on the roads. This may mean that the species is relatively rare and that the record shown in Table 2 indicates that the coyote is a relatively important enemy.

Northern California Kangaroo Rats were widely distributed on the monument during the period of investigation. From numbers seen on the roads, incidence of burrows, and trapping results, they seemed to be roughly three times as numerous in June 1937 as in June 1936, and their occurrence in scats for the early summer of 1937 bears this out. A partial explanation of the rapid drop in the percentage of occurrence of this species, which was found in midsummer, may be that the earlier high represents the destruction of a seasonal, vulnerable surplus above the later carrying capacity of the area.

Desert Harvest Mouse. This form appears to be largely limited to the northern boundary of the monument, where it is rare. It is somewhat more numerous farther out on the refuge. The effect of coyotes on this small population is not indicated by the material examined.

White-footed Mouse. The Gambel white-footed mouse is probably the most abundant mammal on the monument as it is elsewhere in California (Grinnell, 1933). The data indicate that while the mouse is of some importance to the coyote, the coyote is not an important predator of the mouse. Owl pellets from the region suggest that some form of *P. crinitus* makes up about 7 per cent of the white-footed

mouse population but the few upper cheek teeth found in the coyote material were all of *P. m. gambelii.*

Dusky-footed Wood Rats are locally abundant, but total numbers on the monument must be much smaller than those of the *Bushy-tailed Wood Rat.* The coyote appears to be a much more important enemy of the former than of the latter, probably because differences in habitat and nest construction make for differential availability.

The Peale Meadow Mouse is probably of greatest significance to man of all the wild mammals in the farm lands on and near the refuge. In 1936 it was enormously abundant, and was the most important single food of the coyotes on that part of the monument adjacent to the refuge. In 1937 this mouse appeared to be only about 1/100 as numerous as in the previous year, and if this figure is at all close to correct, consideration of the statistics from the scats suggests that while the coyotes are too few in periods of mouse abundance to be an effective control, they may be much more important in periods of scarcity, and may thus delay the upswing. This apparent violation of the generalization that availability determines the amount of predation is probably explained by the fact that, in the summer of 1937, the mice were fairly common in scattered localities and practically absent over large areas where they were found in 1936. Thus their availability to predators hunting in the proper places would be greater than their representation among the numbers of mice would imply. Meadow mice do appreciable damage in the barley fields adjacent to the monument except in periods of greatest scarcity. Probably a large part of the meadow mice found in the scats were killed on agricultural land by coyotes on their way to and from water.

Yellow-haired Porcupines are rather rare on the monument, hence the four scats containing their remains may indicate that the coyote is their most important natural control, though the evidence is inconclusive. The Biological Survey is killing coyotes on the adjacent Modoc National Forest, and with the Forest Serivice is poisoning and shooting porcupines in the same area.

Taylor Pikas are found over the greater part of the monument and the coyote pressure on them appears to be slight.

Washington Jack Rabbits though widely distributed, are not very abundant in this region. They were commoner in 1936 than in 1937, but so far as I could learn have not in a good many years, if ever, reached a high population peak. Heavy predation in the area may possibly be a factor in holding them to a relatively stable level. It is difficult to evaluate the part the coyote plays in the general predation because bobcats, eagles, horned owls, American and ferruginous rough-legged hawks, and red-tails, have all been observed to prey on jack rabbits on the monument.

Washington Cottontail. This species requires considerably denser cover than the jack rabbit and appears to be more nocturnal in its habits, so that the diurnal raptors are probably much less important in its ecology. The coyote, therefore, is doubtless an important—quite possibly the most important—animal preying on it. Numbers of cottontails were apparently not greatly different in the two years,

despite the heavier consumption by coyotes in 1937, as shown in the chart (Fig. 2), and I am led to conclude that: cottontails are an important, staple food for coyotes on the monument; even in 1937 the cottontails killed by coyotes were a small enough part of the population to leave the surviving numbers relatively constant; in 1936 light coyote predation reflected not so much a difference in cottontail numbers as the presence of great numbers of meadow mice; gooseberries, when available enormously lessened the coyote pressure on vertebrates in general, but especially on cottontails.

Deer present a greater difficulty in interpretation than any other coyote food, almost entirely because of their very large size. The monument deer population varies greatly with the season. They are practically absent from June till about November and then move in rather rapidly, so that by mid-winter there may be 1,000 or even more. The numbers decrease again in the spring as the snow on the higher ground disappears. In 1937 and in the spring of 1938 there was a distinct browse-line on the mountain mahogany over much of the monument, and it is perfectly obvious that despite the hard seasons of 1936–37 and 1937–38, the winter deer population is fully as high as the range can carry without serious deterioration, so that anything the coyotes may be doing to hold this population down to its present level, or even to reduce it slightly, is to be credited to the predator rather than debited to it. (The serious overpopulation of deer on the adjacent Modoc Forest was reported by the Forest Service to the Select House Committee on Wildlife Conservation of the Seventy-fifth Congress.)

The problem remains as to just what is the meaning of deer hair found in 74 scats, none of which, by the way, seemed to have been derived from spotted fawns. The average length of life of Rocky Mountain mule deer which become adult seems to be in the neighborhood of 10 years, so that about 1/10 of the adult deer which enter the monument might be expected to die yearly. A conservative estimate of the annual fawn crop would be about one fawn from four adults (including as adults the fawns of the previous year). In a stable population, about 40 per cent of these fawns would replace adults, and 60 per cent would have to be eliminated. Most adults and many of the fawns that die, at least where the winters are hard, perish in that season, mostly from mid-winter onward, so that out of at least 500 deer on the monument at that time it would not be surprising if some 20 to 30 adults, and about the same number of fawns should die, or at least get into extremely poor condition. In considering the effect of coyotes on deer, such weakened animals are what might be called "statistical carrion," since it makes no difference (in a deer population) whether coyotes actually pull them down, or find them dead a few days later. Of course coyotes do kill perfectly healthy adult deer at times, and probably do so ocasionallly on the Lava Beds, though light snowfall and other conditions would seem to favor the deer there. Deer killed by trains on a railroad near the monument, and eaten by coyotes, are probably not represented in my material because of distance from collecting sites, but deer

killed or wounded by hunters along the south edge of the monument are quite probably represented.

Supposing for the moment that all the deer eaten are coyote kills, we would still have to assign most of the deer meat eaten to carrion, because if a coyote kills a deer, the next coyote that gets a meal from the carcass is eating carrion, and so, also, is the killer if he returns for a second meal. In scats collected in spring, summer and early fall, that contain deer remains, blowfly maggots or pupae frequently indicate carrion origin, and in other scats pieces of metatarsals, metacarpals, tail vertebrae, etc., suggest that the tastier parts of the carcass had already been eaten, but even the total of all such indicated meals of carrion is probably much less than the true number.

Leaving the question of how the deer died, there is still the problem as to how many carcasses were eaten by coyotes. There are two methods of approach to this problem. We may take maximum figures for the deer population and estimate how many deer can be spared annually with the population still remaining (as it does) at a relatively stable level. Suppose that 1,000 deer enter the monument yearly, that all deaths occur within its boundaries, and that each two adult deer produce a fawn. We would then be able to spare 60 adult deer and 120 fawns, or 180 deer a year to coyotes. The other approach is by comparison with data for sheep. During the first period of scat collection, 12 sheep (according to the herders) were killed by coyotes on the monument and eaten by them, and about three others died on the monument or along its boundaries. During that period seven scats containing sheep's wool were collected, and 48 with deer hair. If it be assumed that the same number of scats containing hair will result from coyotes eating one deer, as scats containing wool are produced from their eating one sheep, then, since 7 wool-scats were found when 15 sheep were eaten, the 48 hair-scats found in the same period should represent 103 deer. The 74 scats that contained deer hair found during the whole period of collection would present, using the same ratio, a total of 159 deer. But since sheep's wool is probably easier to avoid in eating than is deer hair, since a few of the sheep were skinned, and since a meal of wool felts in the stomach and may often appear in only one scat, whereas a meal of deer hair appears in several, 159 deer is probably too high a figure. The situation with respect to timber wolves and big game in Minnesota as outlined by Olson (1938), especially in his "General Conclusions" (pp. 335–336) seems strikingly similar to the deer-coyote relationship on the monument.

Domestic Sheep. During 3 months of the first period of scat collecting there were about 10,500 sheep grazing on the monument (old grazing permits granted under a former administration are being allowed to run, though no new ones are issued). As already stated, only 12, or less than 0.12 per cent were reported killed by coyotes. Since the coyotes could not be shot, trapped, or poisoned on the monument, this indicates what unfailing care and constant alertness can do to protect sheep from a relatively large predator population.

According to McLean (1934), the

cost of trapping a coyote in California game refuges averages about $14.00. According to Mr. Fairchild of the Tule Lake Refuge, the cost in that general region is much less, only about $1.40 for the Biological Survey. No coyotes would, of course, kill no sheep, but even a few coyotes might wreak havoc among sheep that strayed away or were neglected by the herders. Only a very large (and hence temporary) overpopulation of coyotes would greatly endanger sheep that were properly cared for. It thus seems that even if they could control coyotes for $1.40 each, the local sheepmen could hardly justify, on an economic basis, any very heavy control program, even off the monument, if they had to pay for it themselves instead of getting it done "free" by the government.

Other Stock is not allowed on the monument, though an occasional horse or steer strays in. Carcasses are sometimes dragged to the edge of the monument by neighboring ranchers, and a horse was successfully used as trap bait on the refuge in the winter of 1936–37 about 15 yeards from the north monument boundary. I have heard no complaints of calves or colts being killed by coyotes close to the monument.

Wild-fowl Nests were doubtless much more numerous on the monument in 1937 than in 1936 since the open water was so much closer, but the difference in coyote predation was probably not great since the coyotes had to go to the lake for water, and so passed through a nesting area anyway. Out of the 71 analyzed samples collected in May, June, and the first half of July, only 3 contained wild-fowl eggs, and one of these, attributed with a query to pintail, may possibly actually be pheasant, since fragments 3 or 4 millimeters across were not certainly identified. With so few facts available, it is impossible to arrive at a reliable estimate of total nest destruction by coyotes except to say that it is small. Even if the exact figure could be arrived at, the *percentage* of nests destroyed could not be obtained, since the Biological Survey does not have figures for the total number of duck and goose nests that might be available to monument coyotes. Only half a dozen duck nests were found on and near the monument, during the period of study, by National Park Service personnel, and these (pintail and mallard) were all successful. From the early collection dates of the two scats definitely containing wild-fowl eggs, the possibility is suggested that as in the case of the crows studied by Kalmbach (1937), coyote pressure is less in June and July than earlier in the season.

Other Bird Nests are widely distributed over the monument, and probably more of these are destroyed than are those of wild fowl. Ground nesting species as the horned lark and meadowlark are probably most preyed upon. There is nothing, however, to indicate that any species is suffering unduly from nest destruction by coyotes. It is rather surprising that pheasant and quail eggs were not definitely represented, especially along the north monument boundary where they are abundant in season.

Wild fowl (exclusive of eggs) are obviously most subject to coyote predation during the nesting season, when females may be seized on the nest and newly hatched young may be caught

going from the nest to water. No scats containing remains of downy ducklings were found.

Coyotes unquestionably catch a good many cripples during and just after the hunting season, but the effect of this type of predation seems unimportant to the wild fowl. Many of the cripples would die of their wounds, starvation, or exposure, if they did not first fall prey to the numerous other carnivorous birds and mammals of the region.

Other Birds (exclusive of eggs). Small passerines especially, are taken, and young pheasants would also appear to be eaten, in some numbers. Pheasants, however, are so numerous on and near the northern edge of the monument, that the percentage of the available young killed by coyotes is probably small. The likeliest explanation of the presence of parts of a sparrow hawk in one scat, would appear to be that it was carrion.

Reptiles. Lizards are probably of little importance to coyotes, and the converse is equally true. Snakes seem to suffer a good deal more, especially the gopher snake, which is probably the commonest species on the monument. It is interesting that E. L. Sumner, Jr. (in conversation), reports that he found that the gopher snake was probably the most frequent single destroyer of duck eggs on the Los Banos refuge when he was stationed there.

Grasshoppers are sometimes very abundant on parts of the monument and near it, and though coyotes eat them, they appear to play but a slight role in the predation upon these insects.

ECONOMIC EVALUATION OF KILLS BY COYOTES

Murie (1935), in his paper on coyotes of Jackson Hole, tabulates the kills by coyotes as being of harmful, beneficial, or neutral effect to man. Biological relationships in the Lava Beds region are so complex that such a simple treatment here would appear to be of doubtful significance. For example, deer are considered to be of economic benefit to man, yet because of local over-population of deer, coyotes that kill them on the monument benefit man and the surviving deer as well. Another example is the meadow mouse which, on areas adjacent to the monument, is the most harmful mammal present during its periods of abundance, yet at that time the large kill by coyotes is probably of neutral effect, whereas, when the meadow mice are few and the coyote itself may be, because of its preying on sheep and turkeys, the most harmful mammal near the monument, its predation on the mice may be of great future benefit to man by delaying increase of the rodent to its maximum numbers.

Perhaps we can best say that although, to some extent, every vertebrate species on the Lava Beds National Monument affects the coyote, and is in turn directly or indirectly affected by this predator, it appears that the coyote plays rather a minor role in the ecology of any of the species it preys upon. Our present knowledge does not make it possible to rank the prey species in the order of the effect of coyotes upon them, though it is probably safe to conclude that waterfowl are well down in the list.

CONCLUSIONS

1. Two hundred seventy-three droppings and 9 stomachs of coyotes were examined from the Lava Beds National Monument, in Siskiyou and Modoc Counties, California. The samples were collected in 1935, 1936 and 1937, and represent every month of the year except February.

2. Seven hundred six probably non-carrion items were identified of which 481 (65.18 per cent) were mammals, 20 (2.86 per cent) were birds, 6 (.81 per cent) were bird eggs, 8 (1.08 per cent) were reptiles, 145 (19.65 per cent) were insects, and 46 (6.23 per cent) were vegetable items. *Of waterfowl and eggs of waterfowl, there were only 6, or .81 per cent,* though the scat collections were ample in the nesting season, when both these items would probably be most available.

3. Nineteen species of wild mammals, representing 8 families in 4 orders (Felidae 1 species, Sciuridae 6 species, Heteromyidae 2, Cricetidae 5, Erethizontidae 1, Ochotonidae 1, Leporidae 2, Cervidae 1 species), and 7 species of birds, or bird eggs of 3 orders (Anseriformes 3 species, Galliformes 2 species, and Passeriformes 2 species), have been identified, as well as 2 species of lizards and one snake.

4. Any attempt to evaluate the *effects* (as distinguished from activities) of a single predator, such as the coyote, on the monument-refuge area is complicated by the fact that at least 34 other predatory species are also present continuously, or from time to time, some of them in very large numbers, so that it is difficult to separate the effects of a single predator on a given prey species. The larger the prey, the less difficult this separation is, since there are fewer predatory species capable of preying on it.

5. No evidence was found to suggest that it is necessary or even advisable to trap, poison, or otherwise control coyotes on the Lava Beds National Monument.

SUPPLEMENTARY NOTE

Because May seemed to be the most important month in the relationship of coyotes to waterfowl, Mr. Fisher was requested to obtain more material in that month in 1938. Accordingly, he collected 19 scats which were analyzed as before (the analysis of two of the scats was kindly checked for me by C. C. Sperry of the Biological Survey, who identified the horned lark and blackbird from fragmentary feathers). Fifty-four food items were identified as follows: marmot 4 (7.41 per cent of all items); Oregon ground squirrel 1 (1.85 per cent); golden-mantled squirrel 1 (1.85 per cent); kangaroo rat 1 (1.85 per cent); meadow mouse 23 (42.61 per cent); house mouse (*Mus musculus* ssp.) 1 (1.85 per cent); porcupine 1 (1.85 per cent); jack rabbit 3 (5.56 per cent); cottontail 4 (7.41 per cent); deer (number of scats containing) 5(9.26 per cent); duck (feather fragments) 1 (1.85 per cent); mallard eggs 1 (1.85 per cent); pintail ? eggs 1 (1.85 per cent); pheasant 2 (3.70 per cent); pheasant eggs 1 (1.85 per cent); horned lark 1 (1.85 per cent); red-winged blackbird 1 (1.85 per cent); velvet ant (Hymenoptera: Mutillidae) 1 (1.85 per cent); grass 1 (1.85 per cent). There was also a botfly larva in a scat containing *Microtus* and *Sylvilagus*. The house mouse, pheasant eggs, red-winged

blackbird and velvet ant are items not found in the earlier material.

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A METHOD FOR DETERMINING THE RELATIVE ABUNDANCE OF *MICROTUS PENNSYLVANICUS*

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There is, apparently, cyclic variation in the numbers of many species of mice. In some the population increases to such an extent as to do considerable damage to crops. If increase to dangerous proportions could be detected in a simple inexpensive manner, control measures could be applied before serious damage occurred. The method described in this paper appears to be of value in determining relative levels of field mouse populations.

Method of Procedure

The data on which this paper is based were collected near Ann Arbor, Michigan, in connection with a graduate research project under the direction of Professor H. M. Wight, School of Forestry and Conservation, University of Michigan. To develop the method outlined, the field mouse, *Microtus pennsylvanicus*, was used as it is very abundant in the vicinity of Ann Arbor. Graham (1929) states, " . . . it is suggested that instead of the slow and difficult trapping methods of estimating mouse abundance that the abundance of these animals be measured in terms of their effect upon some standard food presented to them in a standard method." The project was worked out with this suggestion as a guide.

The problem was approached with the point of view that the population density of the field mouse varies with changes in the cover type. The areas on which the trials were made were mapped by types based on plant succession and density (Wight, 1933). Oatmeal was used as a bait and was placed on the ground where mice naturally feed and beneath plant cover to prevent disturbance by birds. The bait line consisted of twenty baits (each a small handful of oatmeal) placed ten feet apart in a straight line. One bait line was formed in each cover type and observations of the disturbances were made daily. Additional observations related to maximum and minimum temperatures, wind direction and velocity, precipitation, and species of animal causing the disturbance. Shrews and *Peromyscus* occasionally disturbed the bait, but such intrusions were easily distinguished by the size and shape of the feces. Scats of *Peromyscus* differ from those of *Microtus pennsylvanicus* in that they are slightly smaller and somewhat more pointed.

In the first trial of the method, four bait lines were placed, each in a different cover type, namely: 1, mixed herbaceous, made up primarily of Canada thistle and wild lettuce; 2, upland shrub with panicled dogwood predominant; 3, mixed grass and herbaceous; and 4, upland grass and sweet clover. Observations were made daily for eight days. No disturbances were noted in type 1, two in type 2, seventy-one in type 3, and none in type 4. After the bait line observations were completed, two traps were set at each bait spot. Six days of trapping resulted in catches as follows: one in type 1, none in type 2, thirty-four in type 3, and two in type 4.

Type 3 consisted of a mixture of herbaceous plants, with much ragweed and a heavy ground cover of shorter weeds and grasses, all of which afforded excellent protective cover. The remaining types were more or less open and of decidedly less value as cover.

In the second trial of this method, eight bait lines were placed, each in a different type of cover. The bait lines were run for six days, following which two traps were placed at each bait spot and trapping was continued for another six days. In the following summation the first number after the type name denotes the number of disturbances noted and the second the number of mice caught. The results by types were as follows: (1) Mixed herbaceous—28—6; (2) clover—13—4; (3) alfalfa—0—0; (4) short timothy—11—8; (5) fencerow (grass)—14—4; (6) timothy and other grasses—71—14; (7) timothy and mixed herbaceous—5—3; and (8) upland pasture—0—3.

Both of the trials indicate a close correlation between the number of disturbances and the catches within the type. That the population density of the field mouse varies with changes in cover type and density is also clearly indicated. It would appear, therefore, that variation in population may be measured with reasonable accuracy by the bait-line method.

After the second trial was made, trapping was continued with 356 traps on 2.03 acres in type 6 (timothy and other grasses) until no more mice were caught. Sixty-two additional mice were caught in eleven days making a total catch of 84 or 41.37 mice per acre. In terms of a probable average, the population density of type 6 could be stated as 40–45 mice per acre. By simple proportion, averages for each of the other types would be: (1) 15 to 20; (2) 5 to 10; (3) 0 to 5; (4) 5 to 10; (5) 5 to 10; (6) 40 to 45; (7) 0 to 5; (8) 0 to 5. The probable average population for the entire area is 8.8 to 13.7 mice per acre.

SOURCES OF ERROR

1. Occasional difficulty in detecting use of bait.
2. Occasional difficulty in distinguishing between signs of species.
3. Possible repellent effect of traps.
4. Disturbance of bait by other animals.
5. Seasonal migrations of mice.

CONCLUSIONS

1. The field mouse population appears to vary with changes in cover type and density.
2. The population density seems to vary directly with the amount of protection afforded by the plant cover.
3. The variation in the population density of the field mouse can be measured with a reasonable degree of accuracy by the use of bait lines.
4. The method is simple, inexpensive, and easy to apply.

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Shade-grown 3 year old sprouts of Grey Birch heavily browsed by deer.
Maximum height 16 inches.

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THINNING FOR BROWSE

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Slashing for the production of browse is today a standard game management practice. In New England and New York, much of the best game range is on lands formerly in agriculture now reverting to forest. Some areas are stocked with stands in which the proportion of inferior hardwoods is undesirably high. They may result from the pioneer forest community invading grassland or from excessive cutting. Of the Northern Hardwoods, aspen, grey birch, and red maple are persistent and aggressive sprouters. When clear-cut, vigorous stumps of these species produce an abundance of coarse sprouts of low palatability. The sprouts often are 3 feet tall at the end of the first season and in 3 to 5 years grow to such size as to furnish little browse. Slashings in such stands are costly to maintain and the effect of frequently repeated cuttings upon plant succession and upon the soil is not well understood.

A tract of second-growth hardwood on the writer's forest at Stephentown, New York, was marked for improvement in the fall of 1935. This area is a spring to early winter range for deer, the animals remaining until the first deep snow. The stand was 20–30 years old, with 1,000 stems per acre ranging from 2 inches to 9 inches d.b.h. By number, 35 per cent were better hardwoods (ash, red oak, sugar maple, black cherry, yellow birch) and 65 per cent were inferior hardwoods (*Ostrya*, soft maple, aspen, grey birch), with abundant advance reproduction of sugar maple and a scattering of small hemlock. A crown thinning, aimed to free all satisfactory trees, removed 25 per cent of the stems, chiefly grey birch and soft maple.

The effect of this winter thinning upon browse production was astonishing. The additional light stimulated the growth of herbs and ferns without encouraging coarse annuals or grasses. The stumps sprouted much less vigorously than did those exposed to full sunlight. Sprouts were mostly less than 18 inches tall and much slimmer than where open-grown (Plate 6). To anyone acquainted with the mechanics of deer browsing, it will be apparent why the animals prefer these smaller and daintier shoots. In this case, the deer nipped back the sprouts almost 100 per cent. Heavy use continued up to the winter of 1938.

After three growing seasons, the effect of the crown thinning is beginning to disappear. Reduced light and heavy browsing have kept the sprouts small and their palatability high. Some stumps have died and it is probable that, by 1946, when the next thinning is due, most of them will have succumbed. Inasmuch as the stand still contains 60 per cent of inferior hardwoods, this process can be repeated at least twice. Beyond that, results are a matter of specu'ation.

The writer believes that a system of frequent thinnings in younger hardwood stands has great promise. It is a straight silvicultural operation intended to improve the quality and growth rate of the timber crop and as such its cost would be charged to the stand itself rather than to wildlife

management. It will produce a continuing crop of highly acceptable browse over a long period without undue exposure of the site and without soil deterioration. It causes no major upset of the plant community on the forest floor. It can be handled by any competent forester at a reasonable cost. There is no added fire hazard. Moreover, it will leave, at the end, a good timber stand instead of a barren.

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A LOCAL STUDY OF PREDATION UPON HARES AND GROUSE DURING THE CYCLIC DECIMATION

Marius Morse

In an effort to determine accurately the relative abundance and distribution of wildlife in the Cloquet Valley State Forest during the winter of 1935–36, an inventory was made on a 2,520 acre (nearly 4 square miles) game management sample area in the north central portion of the forest, which lies in St. Louis County, Minnesota.

Though many interesting data were obtained, it developed that the most significant information pertained to the effects of raptors and mammalian predators upon the ruffed grouse (*Bonasa umbellus*) and snowshoe hare (*Lepus americanus*) populations. It is realized that some of the conclusions are based on very limited data but it is believed they may be of value at least as "leads" to further investigation and to ultimate solution of certain problems involved. The writer wishes gratefully to acknowledge suggestions offered by Dr. Gustav Swanson on the preparation of this paper.

Of considerable importance was the fact that the study was in progress during a period of cyclic decimation, as indicated conclusively by seasonal census figures. A spring grouse census taken April 8–10, 1935, disclosed a total of 199 birds on the area. This figure was based on the flushing of 17 different birds from the 33 miles of census lines. In the fall of the same year, October 30–November 1, another census showed a decrease of 62 per cent, that is, to 75 birds on the 4 square mile area. Whether or not young of the year were present in this population residue could not be determined, although during late June several hens with from 6 to 8 young per brood had been seen.

A mid-winter census on January 9 and 10, 1936, indicated a population of only 36 grouse, but since this figure was based on the flushing of but three individual birds, its accuracy was questioned. However, the spring census taken 3 months later April 1–3, 1936, again resulted in the calculation of a very low population—32 birds. This figure was based on the flushing of 11 individuals and was, therefore, believed to have been more accurate.

By fall of 1936, the population showed a gain to 81 birds, an increase of 153 per cent over the spring population of that year in contrast to the 62 per cent decrease in population from spring to fall of the preceding year. By the spring of 1937, however, the population had again dropped, this time to a calculated total of 25 birds. Apparently the most significant decline occurred during the summer of 1935 when heavy adult, as well as juvenile, mortality depleted the ranks of the grouse. This is in direct contrast to the survival of young during the summer of 1936 when an appreciable gain in population was registered. Seasonal census results with periodic population gains or losses are presented in Table 1.

The snowshoe hare population during the same period showed a similar trend although the losses through the summer

TABLE 1

RUFFED GROUSE POPULATION ON ABOUT FOUR SQUARE MILES OF THE CLOQUET VALLEY STATE FOREST, MINNESOTA, AND ITS FLUCTUATIONS, 1935–38

Census Date	*Population*	*Gain or Loss*
April 9, 1935	199	
Nov. 1, 1935	75	−124
Jan. 9, 1936	36	− 39
April 1, 1936	32	− 4
Oct. 12, 1936	81	+ 49
April 20, 1937	25	− 56
March 27, 1938	60	+ 35

of 1935 probably were not nearly so sweeping as those of the grouse. The hare census was not begun until the fall of 1935 but an estimate of the spring population on the area, based on the number of animals observed from the census lines, placed the number at approximately 1,000 individuals or 250 per square mile. Green and Shillinger (1935) calculated approximately 220 per square mile for the same time on the Lake Alexander area in northern Minnesota. By January, 1936, the population of 1,000 hares had decreased to 369, and by April, 1936, to 177. The October, 1936, census revealed a total of 445 hares on the sample area, an indication of appreciable juvenile survival during the breeding season in contrast to loss in the preceding summer. Table 2 summarizes the hare census results.

Typical of the forest as a whole, the sample study area is largely occupied by second-growth white birch (*Betula papyrifera*) and aspen (*Populus tremuloides*), with lesser amounts of conifers (up to 70 feet in height) including balsam fir (*Abies balsamea*), Norway pine (*Pinus resinosa*), white pine (*Pinus strobus*), white spruce (*Picea glauca*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*). Balsam fir is by far the most common conifer and is well distributed over most of the area, occurring usually in small clumps mixed with other species and affording excellent wildlife cover. Where pine occurs, it usually predominates. Black spruce and white cedar (*Thuja occidentalis*) are confined to 7 small swamps well scattered over the tract.

The most important brush species are: hazel (*Corylus* sp.), willow (*Salix* spp.), mountain maple (*Acer spicatum*), pin cherry (*Prunus pennsylvanica*), alder (*Alnus incana*), and honeysuckle (*Lonicera* spp.). Hazel is the most abundant species and all are quite evenly distributed with the exception of mountain maple which is restricted chiefly to one large hardwood area.

The unusually mild weather that prevailed throughout the month of December, 1935, and the first half of January, 1936, was in direct contrast to the severe cold wave that followed for a period of 40 days when temperatures ranged from 0 to −40 degrees Fahren-

TABLE 2

SNOWSHOE HARE POPULATION ON ABOUT FOUR SQUARE MILES OF THE CLOQUET VALLEY STATE FOREST, MINNESOTA, AND ITS FLUCTUATIONS, 1935–38

Census Date	*Population*	*Gain or Loss*
April 9, 1935	1,000 (Estimate)	
Nov. 1, 1935	970	− 30
Jan. 9, 1936	369	−601
April 1, 1936	177	−192
Oct. 12, 1936	445	+268
April 20, 1937	75	−370
Fall, 1937	100 −	?
Spring, 1938	100 −	?

An estimated 110 hares shot by trapper from Oct., 1935 to Jan., 1936.

Total of 22 hares were shot for disease investigation in February, 1936.

No hares seen on census lines in fall, 1937, and spring, 1938; population estimated at 100 or less.

heit. By January 3, 1936, the snow in the forest had reached a depth of 13 inches, and a maximum for the winter was attained on February 13, when snow on the level measured 32 inches in depth.

During the period from December 3, 1935, to April 1, 1936, in making wildlife observations, a total of 39 days were spent on the sample area, distributed by months as follows: December, 13 days; January, 14; February, 9; March, 2; and April, 1. All but a few of the observations were made by a trained CCC field assistant, Otto Kuehne, whose work, as determined by constant checking, was consistently thorough and accurate. This field study was a part of the game management program assigned to Minnesota State CCC Camp S-51.

Weekly observation procedure consisted of following random compass lines over the 2,520 acre area so that reasonably thorough coverage of the tract was obtained. Brushed out one-sixteenth lines and marked corners aided greatly in accurately locating field observations. The observer was required to record in detail in a field notebook a description of each observation at the time it was made. The notes were later edited, tabulated by species, and mapped for future reference and interpretation.

Raptors were by no means scarce on the sample area, a conservative estimate being that about 12 individuals were present, ranging over part or all of the tract. Whether or not this density of perhaps 3 raptors per section represented a normal winter population could not definitely be determined but it is believed to have been somewhat of a concentration. A total of 32 field observations on raptors, exclusive of "sign," were recorded. These involved the horned owl, barred owl, goshawk, and raven. So far as could be determined, these were the only species present.

A single record was obtained of a barred owl feeding on a "freshly killed" hare. Goshawks were observed on 11 different occasions. In 3 instances, they were feeding on "freshly killed" snowshoe hares and in 5 other instances were flying low, apparenty searching for food. A breeding record of the goshawk had been obtained for the area in May, 1935, when a nest with eggs was discovered 20 feet up in the crotch of an 8-inch Norway pine. The nest, however, was deserted later when one of the adults was shot

Most of the positive field observations were of the following 5 main categories: snowshoe hare sight records, snowshoe hare "kills," ruffed grouse sight and evidence records, ruffed grouse "kills," and raptor sight records. Study of the distribution maps revealed a concentration of observations of each of these types in one square mile of the area, characterized by exceptional interspersion of cover types, including both coniferous and nonconiferous species. Not less than 39 per cent of all the observations were made in this single square mile. A total of 71 per cent of the grouse "kills" noted were located there. The apparent high concentration of ruffed grouse and snowshoe hares, and therefore "kills" of these creatures on this area could apparently be attributed to the unusual mixture of food and cover types it afforded. Raptors may have moved

in to take advantage of the increase in available food.

The census method used for ruffed grouse was that developed by R. T. King and involves the counting of birds flushed on sample strips through the area along lines equally spaced at quarter mile intervals. The population estimate is calculated from the number of birds flushed, the average flushing distance, the total length of the sample strip worked, and the size of the census area. King and others have demonstrated that this method yields reliable results. During the cycle "low," when only a small number of birds can be flushed on the census lines, the method has never actually been checked by the writer for accuracy. Probability would suggest that at such times the degree of accuracy would be lowest, yet seasonal censuses by the strip method seem consistently to have reflected the growing scarcity of birds as indicated by random inventory observations on the census area.

The writer has attempted to improve upon this technique with special reference to periods of cyclic decimation when grouse are relatively scarce. As has been mentioned, the winter census of 1935–36 resulted in the flushing of only 3 birds on the census lines. Only 2 were observed and flushed from the census lines the following spring, so it was decided that the observer should "run" random compass lines through the area until flushing distance records had been obtained for a minimum of 8 additional birds. It was believed a much more accurate average flushing distance could thus be obtained by averaging out possible abnormal flushing records of one or two individuals. No attempt was made to eliminate the defects in sampling that might result from dependence upon so small a sample of the grouse population. This might have been done, however, by running lines through sections, a distance of one-eighth mile rather than one-quarter of a mile apart.

The method for counting hares is a modification of King's grouse census technique and was originated by W. L. Webb. It is based on the assumption that hares jumped cannot be seen as readily as grouse flushed by an observer traversing census lines. The sample strip in which all the animals are assumed to have been tallied is consequently reduced in width by basing it on an average "jumping distance," computed by measuring distances at right angles to the census line from the points at which the hares were jumped. The total sampling area is thus appreciably decreased in size. This method, employed for census work nine times since 1935, has registered a progressive decline of the hare population (corroborated by general field observations) and there is every reason to believe it is fairly satisfactory.

The total hare "kill" noted from December 3, 1935, to April 1, 1936, was distributed as follows among predators:

TABLE 3

Predators	*No. Hares utilized and presumably killed*	*Percentage of total*
Raptors	22	75.9
Mammals		
Fox or wolf	2	13.8
Mink	1	
Other	1	
Undetermined	3	10.3
		100.0

This total kill of 29 individuals represents an average of one hare discovered for each 1.3 days spent in the field. On the basis of an observation strip 30 yards wide and an average distance of 8 miles per day covered on foot by the observer, approximately 3.5 per cent of the sample area was covered per day. A 100 per cent coverage of the area was thus obtained in 28.6 days, during which time 20 dead hares were found, amounting to 5.8 per cent of the total number of hares (345) lost December 3, 1935, to April 1, 1936. During the entire time of 39 days in the field, the observer located kills equivalent to 8.5 per cent of all hares lost in the period, and these were discovered at the rate of 0.7 hare per day.

For the period December 3, 1935, to January 9, 1936, raptors, as nearly as could be determined, were responsible for the death of 40 per cent of the 10 hares of those discovered and examined that died from natural causes. As indicated in the table below, mammalian predators accounted for another 40 per cent, while 20 per cent of the deaths could not be attributed to any single decimating factor.

TABLE 4
PERIODIC HARE MORTALITY FROM NATURAL CAUSES

Date	*Kills by Raptors*	*Kills by Mammals*	*Deaths from Unknown Cause*
Dec. 3, 1935 (Start of field work)			
Jan. 9, 1936 (Census)	40%	40%	20%
April 1, 1936 (Census)	95%	0%	5%
Average Percentage	67.5%	20%	12.5%

NOTE: Sample kills discovered (29) used as basis for percentage calculations. Some of deaths from unknown causes may have represented hares that died from disease.

From January 9, 1936, to April 1, 1936, raptors presumably accounted for the loss of 18 out of 19 hares discovered dead or a distinctly greater proportion (95 per cent) than shown in the preceding tabulation. Of these 18 individuals, 12 were fresh "kills," the hares having apparently died the same day the carcasses were found. A single day, February 4, yielded the unusual number of 5 kills all located within an area of not more than a half mile radius. Mammalian predators accounted for no dead hares found during the same period. The cause of death of one hare could not be explained. A total of 17 of the 19 kills were discovered before February 22 by which date all but 3 days of the field work for the period had been completed.

As may be noted from Table 1, ruffed grouse were relatively scarce November 1, 1935. During the period of observation in the field December 3, 1935, to April 1, 1936, only 6 grouse kills were located, raptors appearing to be responsible for the loss of 4 or 66 per cent of them. One kill could not be diagnosed and the sixth bird had been hit by an automobile. The figure of 66 per cent is particularly interesting since it so closely approximates the 67 per cent representing the proportion of hares killed by raptors during the same period.

The limited data suggest that the presence of the abundant hare "buffer" food was not an especially important factor in reducing predation upon grouse. In fact, it may have had the opposite effect. It does not necessarily

follow that the raptor predation on grouse would have been more severe had there been a much smaller hare population because the presence of a large number of hawks and owls might conceivably have been the result of an "invasion" brought on by local abundance of winter food in the form of hares.

On the other hand, if the raptor population present was normal and chiefly resident on the area, it is reasonable to assume that hawks and owls might have seriously depleted the few remaining grouse had not hares been present in sufficient numbers to constitute an important source of food. At least on this one local area then, it appears that the marked population decrease in ruffed grouse preceded that of the snowshoe hare and the "buffer" food value of the hare was accordingly enhanced. The order of decimation is probably significant.

Numerous fresh weasel tracks were encountered many times during the study period, and it was concluded that weasels were at least "moderately" abundant over most of the sample area, yet not a single hare kill that could be attributed to a weasel was observed. The evidence points to the conclusion that this mammal must have been preying on other species, probably mice. On several occasions, however, fresh weasel tracks leading into hare "burrows" were observed, and the possibility remains that an undetermined hare kill may have resulted in the burrows. The findings of Allen (1938) are significant in this regard. His experimental studies with captive weasels and hares suggest that most adult rabbit victims "in the wild must be killed at close quarters, probably for the most part in burrows." His experiments also indicated that a weasel would encounter considerable difficulty in subduing a full grown hare in the open. These findings may explain the absence of weasel kills among hares discovered dead on the sample area.

The term "burrows" as used here refers chiefly to vacated woodchuck or skunk dens and cavities beneath or in old rotting stumps and logs. There were many of these in use by the hares and it was not uncommon for the field observer to see a hare coming out of a burrow, going into one, or sitting beside the entrance. Of the 122 sight records of hares during the period of field observation, 8 were of individuals either entering or leaving burrows. About as many records were obtained of hares using dens during milder weather (above zero) as during colder weather (below zero). Slash piles or the bases of young conifers also were favorite retreats.

The rather extensive use of burrows by hares is an interesting type of behavior for this species during the winter months. Aldous (1937) does not refer to the utilization of burrows and states that forms regularly used by snowshoe hares throughout the year are merely resting places in secluded spots where the hares spend most of the day, during which time they are largely inactive.

Seton (1928), in his remarks on the winter life of the snowshoe hare, makes no mention of the animals frequenting burrows but found that certain individuals he watched the year around used the same 3 or 4 forms in winter as were used on the warmest days in the summer. MacLulich (1937), however, re-

ports that in Ontario the snowshoe hare commonly uses burrows.

Particularly interesting is the indication from the successive hare censuses (the results of which appear in Table 2) that the total calculated loss during the early winter in November and December was considerably heavier than that for the three-month period from January 9 to April 1, 1936, and amounted to 76 per cent of the total reduction in population from November 1, 1935, to April 1, 1936. The meager mortality data available for December, as previously noted, suggest that mammals and raptors each accounted for about 40 per cent of the loss (see Table 4). Information as to mortality in the month of November is regrettably lacking.

Throughout the entire investigation, special effort was made to locate hares that might have succumbed to disease. It would seem that if large numbers had been killed by disease, some of them should have been discovered by the field observer; on the contrary, he was unable even to observe any ailing individuals. The possibility exists that there may have been hare mortality due to sickness, within the burrows, though no evidence to substantiate such a supposition was obtained.

Green and Shillinger (1936) investigated the occurrence of tularemia in snowshoe hares in relation to the cyclic decimation of the animals but reported that tularemia is not a major factor in the die-off. They stated they had recently found in certain localities a marked occurrence of pulmonary disease in snowshoe hares and that, although the nature of the lung infection had not been satisfactorily determined, it appeared that it was not tularemia. Findings later reported by Dr. Green (1938) indicated a definite association between lungworm infestation and pulmonic tularemia in snowshoe hares, and the author concluded that this form of disease may affect some animals chronically and so result in their serving as a reservoir of infection.

Partial disease studies on the group of 22 hares shot in February, 1936, on the sample area (as noted in Table 2) resulted in further findings of significance in this connection. Green, Shillinger, and Larson (1936) stated that "the most striking pathological lesions found at necropsy were those in the lungs. Eighteen of the 22 snowshoe hares had abnormal conditions in the lungs, and in 15 instances these lesions were such as are typically present in the cases of lungworm infection we have studied."

The presence of infectious disease was definitely established in the case of but a single hare. It could not, however, be stated definitely without further microscopic study whether any of the animals were actually infected with the chronic pulmonary disease previously reported. These findings suggest, therefore, that lethal disease in this sample of 22 hares and assumably in the hare population on the sample area may have been of such low incidence as to have resulted in the death of but relatively few individuals at that time.

In a recent publication by Green and Larson (1938) the authors concluded "that the hare population throughout Minnesota was in a process of destruction from shock disease during the winter and spring of 1936," the

same period during which the present study was under way. They further state, in their description of the nature of shock disease, that hares appearing normal under natural conditions in the wild have been seen to leap suddenly into the air in convulsions or sink to the ground in a state of coma, dying in from a few minutes to an hour following the initial symptom.

It is perhaps significant that on no occasion was any evidence of shock disease observed during the course of this study. It would seem that the presence of disease in the hare population, however, might account in part at least for the heavy "predation" on hares by raptors, as an afflicted hare no doubt would be more easily overcome than a healthy individual. Blood stains in the snow were invariably recorded as proof of predation but it is possible that some of the hares had died from shock disease and were preyed upon by a hawk or owl while still warm.

Predation by raptors seemed to increase in intensity as the winter wore on, due possibly either to an influx of hawks and owls into the area or to increasing difficulty in obtaining other food, principally mice, which apparently were protected from them by the added accumulation of snow. Mammals (including the mink, weasel, fox, and wolf), on the other hand, found it easier to prey on mice late in the winter, a time when mammalian predation on hares appeared to be negligible.

Of much greater significance than the heavy winter mortality of grouse and especially hares, as an indication of the cyclic decline during the period of this study, was the marked decrease in the total population of the ruffed grouse from spring to fall of the 1935 breeding season. Breeding adults not only reared to maturity few if any young during the summer of 1935 but apparently suffered serious losses in their own ranks.

SUMMARY AND CONCLUSIONS

1. The ruffed grouse and snowshoe hare populations on the Cloquet Valley State Forest, Minnesota, reflected the cyclic trend by decreasing tremendously from the spring of 1935 to that of 1937.

2. Mortality of ruffed grouse was heaviest during the summer of 1935, but the greatest hare decimation, amounting to approximately 68 per cent of the fall population, was during the winter of 1935–36.

3. At least 87 per cent of the hares included in the measurable mortality during the period of greatest loss in winter were apparently utilized by predators.

4. Mammalian utilization of hares was roughly equal to that of raptors in December, 1935, but decreased to a negligible amount in January and February, 1936, when utilization by raptors became unusually high.

5. Weasel predation on hares appeared to be of very low incidence or altogether lacking.

6. Vacated animal dens and other ground cavities were sometimes used by hares for shelter during the winter months.

7. The role of disease as a factor in heavy winter mortality in the hare population could not be definitely determined but appeared to be very

limited. Predators may have been made apparently responsible for large losses through their taking quick advantage of the opportunity to prey upon sick and dead hares.

8. Seasonal censuses indicated that few if any young of either grouse or hares were raised to maturity during the 1935 breeding season.

9. The goshawk, and the horned and barred owls were the principal raptorial species utilizing hares as their chief source of winter food.

10. The possible importance of the snowshoe hare as a "buffer" food of raptors during the winter period when grouse were scarce should not be overlooked.

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WINTER HABITS OF MICHIGAN SKUNKS

Durward L. Allen

On the gravelly slopes and sandy plains of southern Michigan's glacial till the eastern skunk (*Mephitis mephitis nigra* Peale and Beauvois) finds what may well be its optimum living conditions. The abundant fur crop produced in the state by this species and its northern ally (the Hudsonian skunk) is surpassed in value only by that of the muskrat and the mink. Despite its significance as a fur resource and repeated efforts of the Department of Conservation to establish the skunk on the protected list, it still remains an unprotected species. More exact knowledge of the habits and management of skunks was one of the objectives of this department in a recent wildlife investigation at the Kellogg Farm in Kalamazoo County. This project was begun in September, 1935, and continued through July, 1937.

The area studied is 500 acres of sandy loam occupied by the W. K. Kellogg Farm and the W. K. Kellogg Bird Sanctuary of Michigan State College (Allen 1938). The bird sanctuary is 80 acres in extent and lies in the central and southwest portions of the tract which are too hilly for cultivation. It contains a 20-acre pit lake, which is a concentration point for waterfowl. The farm comprises the remainder, with level cultivated fields on the north and east. The area supports extensive coverts of lowland brush around Wintergreen Lake and five marshy kettle holes. There are several stump-filled gullies, patches of upland brush, and a total of approximately 25 acres of upland oak woods. On the sanctuary and adjacent parts of the farm an aggregate of about 20 acres of pines and spruces were planted in 1927.

The excellent cover of the farm has made it very favorable to cottontail rabbits. It also supports a large population of fox squirrels. Pheasants and quail are present, though comparatively few in number. The skunk population is high, 62 individuals having been handled on the 500 acres in one winter season (Allen 1938).

Thanks are due for the cooperation of M. D. Pirnie, Director of the Kellogg Bird Sanctuary, who provided office and laboratory space for the project and directed an accompanying academic program; and C. M. McCrary superintendent of the Kellogg Farm, who contributed numerous records and other favors. Curtis Bartlett was transferred from the State Game Farm, and served as full-time assistant from October to April during both years of the work. The project was administered by H. D. Ruhl, in Charge, and the Game Division staff of the Department of Conservation. Those in particular who contributed to the work are Paul Hickie, F. F. Tubbs, and G. W. Bradt.

Methods

From October, 1935, to June, 1937, a total of 143 skunks were handled on or near the Kellogg Farm. Of these, 83 were first captured in box traps, 22 were taken first from burrows, steel traps caught 31, and 7 were found dead. The largest number of repeats

(*Left*)—Box traps were used in capturing skunks alive.
(*Right*)—Transferring a skunk to a burlap bag.

(*Left*)—Live skunks can be handled safely by a grip on the back of the neck and the base of the tail.

(*Right*)—Removing a skunk from an excavated burrow.

base

for a single skunk was 6 and the average for 89 marked animals, 1.7. Skunks were handled alive 191 times.

Trapping. Box traps covered with one-third inch mesh hardware cloth (Plate 7) were used in capturing skunks alive. From 20 to more than 60 of these were set almost constantly from October to April. Each trap was baited with half a chicken, such bait being nearly always available at the large poultry plant of the Kellogg Farm.[1] On several occasions a skunk tore a hole in the hardware cloth and escaped, but in general the traps were adequate. Inch-mesh fur farm netting has since been found to be a more satisfactory trap covering for this species.

Handling. Handling skunks requires a specialized technique. As the problem of dealing with this species is certain to confront the wildlife technician or anyone who chances to leave open a live-trap of suitable size, this aspect of the work is treated in some detail. The method of handling live skunks went through considerable evolution, and it is described here as finally used. This technique allowed very little chance for an accident if one was cautious; and by its use a skunk could easily be removed from a trap, sexed, marked, and weighed in three or four minutes.

The open wire-covered trap was approached slowly from the up-wind side with a burlap sack or something similar held in front of the operator as protection against a discharge from the scent glands. This bag was spread over the trap and the opening of another stretched across the front. The sliding door was then raised, and the skunk would sometimes walk into the bag. Usually, however, it was necessary to dump the animal forcibly from the trap (Plate 7). By way of precaution several more bags were then spread over the one containing the skunk. The operator knelt on this covering astride the animal and allowed it, under control, to crawl slowly forward to the mouth of the bag until its head appeared. The skunk was then pressed to the ground by a firm grip on the back of its neck, the bag being kept tightly stretched across its back. It was carefully pulled out of the bag until the free hand could grasp the base of its tail. In this manner a skunk can be lifted and safely handled if the belly is kept up and the anal opening directed away from the operator (Plate 8). Even should a discharge occur, in this position it will be harmless if the skunk is pointed down-wind. When held by the tail with its feet in the air, a skunk is fully capable of emitting its scent (Merriam 1886, Dice 1921); and a hold on the base of the tail alone is not a safe method for handling these animals.

It is the writer's impression that male skunks are usually more belligerent than females, but nearly any of the skunks handled in this work would bite if given an opportunity. A pair of heavy leather mittens eliminates any danger from this source, as the fingers can easily be withdrawn from that part of the mitten which the animal bites, and no harm is done. A skunk in a bag is ordinarily quiet unless bumped or jolted, in which case it will often discharge scent. Similar experiences were recorded by Cuyler (1924) in work on the striped skunk (*Mephitis mephitis varians*).

[1] An ear of corn was also present as bait for rabbits and squirrels.

The scent of a skunk is particularly offensive to some individuals (Audubon and Bachman 1849), while it does not bother others (Burroughs 1900). Both dogs and men appear to react in different degrees to a discharge in the eyes (Merriam 1886). Constant association with the odor evidently dulls olfactory sensitivity to it. Throughout the winter months the smell of skunk about the persons of my assistant and myself was readily detectable to others when we could perceive no trace of the odor. Even when, through carelessness, one of us was thoroughly "skunked" on a boot or sleeve, the smell was rarely noticeable to us for more than a day. Lantz (1923) recommends washing in gasoline or chloride of lime for removing the odor. The trappers in the vicinity of Augusta, Michigan, use a mixture of one part oil of citronella and one part oil of bergamot to neutralize the smell on tools and hands. For the same purpose I have found a dilute solution of sodium hypochlorite to be very effective, although it is damaging to some fabrics.[2]

Removal from burrows. When skunk burrows are dug out, the animals often retreat into the farthest passage of the den and at times even attempt to dig away through the sandy soil. When the investigator has dug to within an arm's length of the skunks it is usually safe to reach in with a mittened hand and remove them. The skunk almost invariably opposes its posterior extremity to a groping hand, which position presents the tail as a convenient handle for dragging the animal out. The tail can often be grasped and the skunk removed without disturbance. At times, however, considerable fumbling is necessary and the glove will be soiled with a small discharge. In removing more than 30 skunks from burrows I have never been bitten nor had a skunk emit a large quantity of scent in the burrow. When the tail of a skunk is grasped, the animal digs in all four feet and resists any pull that is exerted. This anchorage is so effective that at times I have found it necessary to insert myself as far as possible into a tunnel, grasp with both hands the tail of a large skunk, and drag the animal out with the assistance of one or more cooperators. As the animal emerges it must be pressed to the ground at the base of its tail and the back of its neck. When a good hold is secured, it can be lifted and dropped into a bag (Plate 8).

Killing. In killing a skunk that is to be handled later it is desirable to avoid emptying of the scent glands, which is the inevitable result of most violent methods. In the region discussed, trappers drown skunks that are caught near a pond or stream. The animal is pushed into the water or beneath the ice by means of a pole. By this method the fur is not soiled. A technique that may be more generally applied is striking the skunk a heavy blow across the lumbar region of the back with a club (Merriam 1886, Lantz 1923, Seton 1929, Bailey 1936). This method has been much employed in these studies and has been found very reliable. If the back is broken at one blow, a nervous reflex discharging the scent glands seems pre-

[2] I have been informed by L. R. Dice that ordinary cold hydrant water, allowed to flow over a pelt, will remove much of the odor. This method has been used in the University of Michigan Museum at Ann Arbor.

cluded. For dissection purposes the method is somewhat objectionable, as it leaves the body cavity partially filled with blood. A cleaner manner of killing that leaves the animal entirely unmarred was developed for our purposes. A number of medium-weight rubber bands were linked together forming a chain about 30 inches long that was attached by a staple to a small block of wood at each end. When a skunk was removed from the trap the chain of rubber bands was wound tightly about its neck. The pressure quickly throttled the animal and when it became quiet it could be placed in a bag for future reference. The main objection to this method was that the rubber bands lost their elasticity in cold weather. The skunks handled never used their scent defence even when strangled if the anal region was pressed to the ground by a hand or foot on the base of the tail. Where facilities permit gassing is an excellent method of killing, and on several occasions we have used ether or chloroform. Bailey (1923) speaks of killing a specimen with carbon bisulphide.

TABLE 1

MEASUREMENTS AND WEIGHTS OF MALE SKUNKS

(Millimeters and grams)

Date	*Length*	*Tail*	*Hind Foot*	*Ear (from Crown)*[1]	*Weight*	*Probable Age Class*
2-17-37	599	225	61	18	2,438	Adult
2-17-37	558	195	60	17	1,786	?
3- 2-37	527	196	65	15	1,588	Juvenile
3- 3-37	595	242	70	13	1,758	Adult
3- 9-37	560	230	67	16	1,644	Adult
3-14-37	569	228	66	16	1,673	Adult
3-15-37	522	207	63	14	1,460	Juvenile
3-16-37	610	245	65	15	1,616	Adult
3-16-37	595	240	70	17	1,517	Adult
3-18-37	564	230	69	15	1,276	Juvenile
3-19-37	561	221	81	17	1,446	Juvenile
3-20-37	582	230	70	14	1,644	Adult
3-20-37	522	198	61	14	1,389	Juvenile
3-20-37	555	217	67	15	2,098	Adult
4- 2-37	598	250	69	14	1,417	Adult
4-22-37	587	231	70	16	1,644	Adult
5- 6-37	587	230	65	15	1,701	Adult
5- 8-37	596	226	69	17	1,814	Adult
Average	571.5	224.5	67.1	15.4	1,661.6 (3 lbs. 10.6 oz.)	

[1] The notch is a much better point from which to measure a mammalian ear (Dice 1927)

Marking. In this study skunks were marked by toe-clipping. The method worked well except for the tendency of these animals to lose toes in traps. Several times identity was uncertain due to this mishap. Although not tried in the study here reported, ear-tagging is a much better method and it is being used in studies now under way.[2]

[2] Investigations at the Swan Creek Wildlife Experiment Station (Game Division, Department of Conservation) in Allegan County, Michigan.

WEIGHTS AND MEASUREMENTS

Of the fall weights of skunks, Seton (1929) says, "By October, the young might pass for adults, but careful comparison shows them to be a little smaller, and much lighter in weight than the old ones. That is, they weigh two to three pounds, whereas the old ones may be double that."[4] Hamilton (1937) found that in New York state there was a weight loss of 13.8 per cent in male skunks from November to February and of 38.0 per cent in females.

In this study the average weight of 33 males handled in the field in February and March (1936 and 1937) was 1,905.1 grams (4 lbs. 3.2 oz.). The average for 30 females was 1,411.8 grams (3 lbs. 1.8 oz.). These figures indicate a difference of 493.3 grams (1 lb. 1.4 oz.) between the late winter weights of the average male and female skunks. Tables 1 and 2 give the weights and measurements of 18 males and 24 females taken in late winter and spring. It will be seen that in this series there was an average difference in length between the sexes of 20.2 millimeters. The heaviest skunk handled was a male found dead and frozen beneath a brooder house on December 6, 1935. It weighed 4,196 grams (9 lbs. 4 oz.).

A few skunks were taken at such

TABLE 2

MEASUREMENTS AND WEIGHTS OF FEMALE SKUNKS
(Millimeters and grams)

Date	*Length*	*Tail*	*Hind Foot*	*Ear (from Crown)*	*Weight*	*Probable Age Class*
2- 3-37	512	210	58	16	964	Juvenile
2-20-37	557	211	57	14	1,134	?
2-21-37	580	231	60	13	1,318	Adult
2-22-37	569	232	59	14	1,290	Adult
2-26-37	581	236	63	17	1,644	Adult
2-26-37	593	246	63	17	1,616	Adult
2-28-37	552	222	64	15	1,474	Adult
3- 3-37	512	190	63	12	1,148	Juvenile
3- 3-37	535	210	64	15	978	Juvenile
3- 3-37	517	205	62	14	978	Juvenile
3- 6-37	518	199	62	14	950	Juvenile
3- 8-37	559	233	63	15	1,106	?
3-10-37	545	223	64	15	1,049	?
3-14-37	594	241	67	18	1,304	Adult
3-19-37	562	229	66	11	1,247	?
3-22-37	526	209	63	15	1,106	Juvenile
4- 2-37	525	200	64	15	1,191[1]	Juvenile
4- 2-37	538	203	64	13	1,134[1]	Juvenile
4-17-37	576	242	66	16	2,098[1]	Adult
4-17-37	530	235	65	14	1,120[1]	Juvenile
4-24-37	567	235	63	15	1,658[1]	Adult
4-26-37	541	233	63	16	1,432[1]	Adult
4-30-37	582	229	64	18	1,191[1]	Adult
5- 8-37	560	212	58	15	1,786[1]	Adult
Average	551.3	221.5	62.7	14.9	1,288.1 (2 lbs. 13.4 oz.)	

[1] Pregnant.

[4] Approximately 907 to 1,360 grams for young skunks.

times that the loss in weight over the winter could be checked. Skunk number 4♂ weighed 3,289 grams (7 lbs. 3 oz.) on December 15, 1935. On the following February 26 it weighed 2,098 grams (4 lbs. 10 oz. Loss: 1,191 grams or 36.2 per cent of the December weight). Another skunk, number 19♂, weighed 2,183 grams (4 lbs. 13 oz.) on November 13, 1935. On March 3, 1936 it weighed 1,389 grams (3 lbs. 1 oz. Loss: 794 grams, or 36.3 per cent of the November weight). A female, number 1 weighed 1,418 grams (3 lbs. 2 oz.) on October 21, 1935, and 1,134 grams (2 lbs. 8 oz.) on March 12, 1936. Loss: 284 grams or 20 per cent of the October weight. On February 4, 1937 the same animal weighed 1,077 grams (2 lbs. 6 oz.). When last handled this female was at least a year and ten months of age. It appeared considerably more emaciated than when it was first taken on October 21, 1935, and was lighter in weight than several juveniles known to be less than a year old. It was larger of frame, however, and could, from this fact, be separated from the young individuals.

Age Differences. In Table 3 are given the weights of 11 juvenile skunks taken in traps during August and early September, 1936. Three of these were females retaken in a burrow on January 12. Each of these juveniles had attained a weight of about 1,200 grams (2 lbs. 10 oz.) by this date. Although weight is not entirely reliable for separating all young and adult individuals, in a large series it apparently will serve to detect most of the juveniles. In the table of measurements it is evident that a small size class exists. There are borderline cases, however, and an age index based on size would not be entirely reliable. Hamilton (1937) separated young of the year on a basis of pelage. No evident difference between old and young was observed in this study by external examination, although few of the pelts were removed. Size and weight are used here as being the best indications of age available, but they are not considered infallible.

BREEDING HABITS

Seton (1929), who reared skunks in captivity, has given an excellent ac-

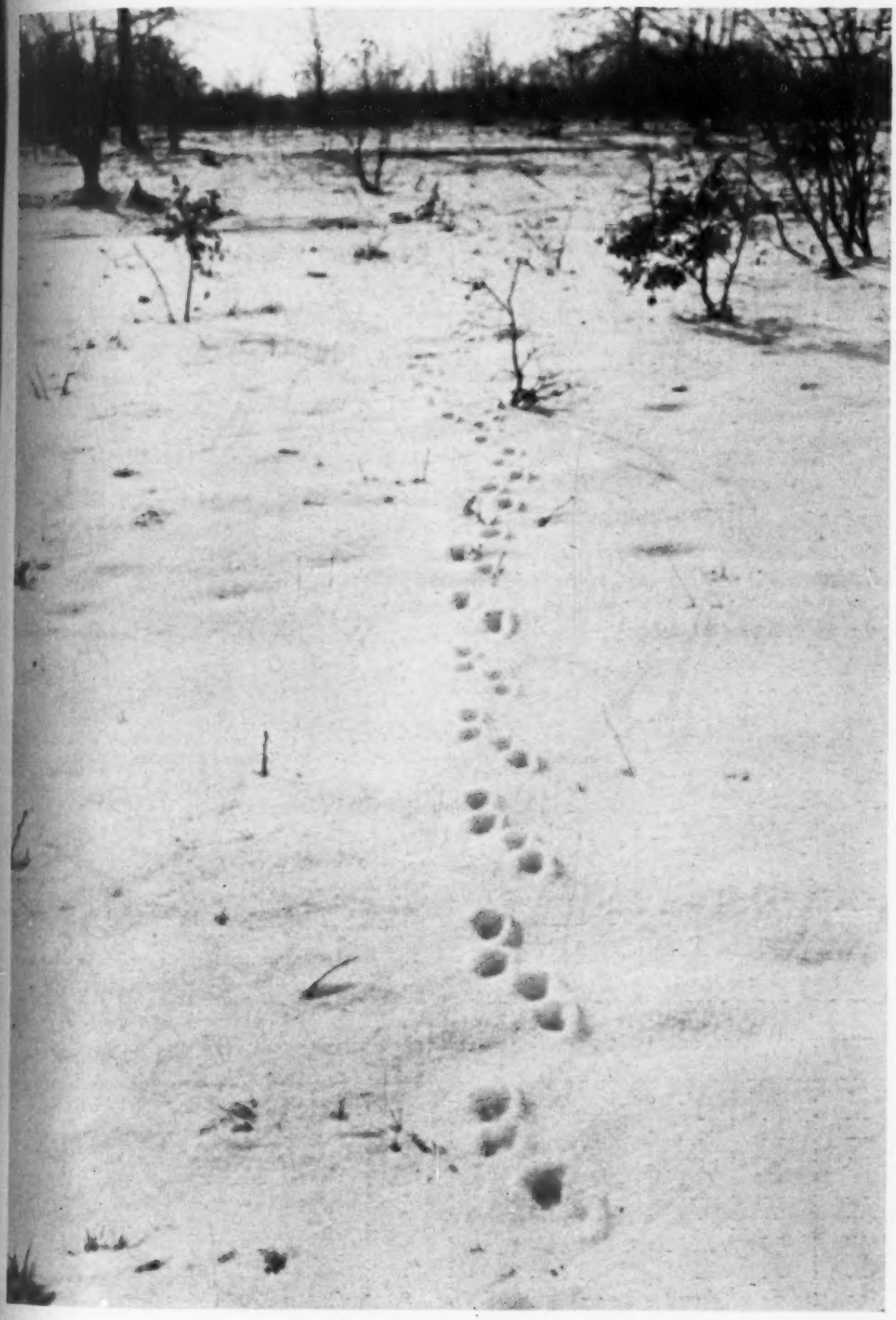
TABLE 3
WEIGHTS OF JUVENILE SKUNKS

Number	Sex	First Taken				Retaken			
		Date	Weight			Date	Weight		
			(grams)	(pounds	ounces)		(grams)	(pounds	ounces)
31	♀	7-17-36	595	1	5	1-12-37	1,276	2	13
32	♂	7-17-36	567	1	4	—	—	—	—
33	♂	7-17-36	822	1	13	—	—	—	—
34	♂	7-17-36	652	1	7	—	—	—	—
36	♀	7-17-36	907	2	0	1-12-37	1,247	2	12
37	♂	7-17-36	964	2	2	—	—	—	—
38	♂	7-17-36	822	1	13	—	—	—	—
39	♂	7-17-36	539	1	13	—	—	—	—
40	♀	7-18-36	652	1	7	1-12-37	1,191	2	10
41	♀	7-24-36	964	2	2	—	—	—	—
42	♀	8-17-36	850	1	14	—	—	—	—

count of the breeding of this species. "In Connecticut, the mating time is mid or late February. I have, however, known it to happen any time between Feb. 1st and Mar. 31st. Old females in Connecticut usually are ready for the male about Feb. 18th. If, in this first heat, they are not mated, a second period occurs some four weeks later. The young females, that is, the young of last year, probably do not come in heat until mid-March." The author states that gestation nearly always lasts 63 days, but that there are unusual extensions of the period up as high as 72 days. He adds, "Therefore, the brood begotten in mid-February is due to arrive (as do many of them) in the last week of April. Those begotten in the end of February appear in mid-May, as do most of them. But broods arriving in early June are not uncommon." The number of young is given as from 2 to 16 and a tendency toward smaller litters in young females was observed. "A young mother usually produces 4 at her first brood, at her second, 6 to 8. The most I have ever seen in a litter was 10."

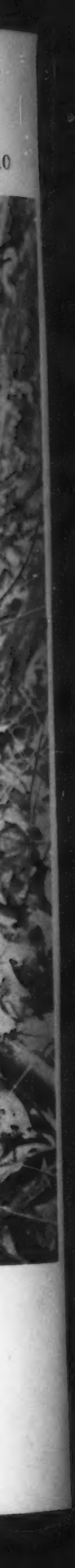
Mating and Gestation. In late February, 1936, two feet of snow that had been accumulating since December melted within a week. Coincidentally with the rise in temperature, skunk tracks (Plate 9), which had been almost totally absent for the month previous, became numerous and animals of both sexes began to appear in the traps. It was strikingly noticeable that many of the tracks were in pairs. In their erratic wanderings over the farm it was frequently observed that one skunk had been walking behind another or close beside it for a long distance. Several similar observations were made in late winter of 1937. Conditions were seldom good for tracking, however, and there is no certainty that the close association of two animals was peculiar to the breeding season.

The only evidence on the point from this work seems to indicate that skunks are polygamous. A definite sex discrimination was apparent in the association of the animals in winter burrows. Of a total of 26 burrows excavated, 4 contained both males and females in the ratio of 1:10, 1:10, 1:7, and 1:1 respectively. Three contained only females (6, 4, and 1) and 4 contained only males (1, 1, 1, and 2). Some of these animals were liberated from burrows already dug out and had redistributed themselves in other dens; but this probably does not greatly detract from the significance of the data. It will be noted that in none of these few cases was more than one male in a den with females. Two males were cohabiting with 10 females each, and another with 7. There was no scarcity of males on the area as there were 79 males and 64 females in the total number sexed (approximate ratio: 55.2 percent males, 44.8 percent females) Whether the males found with females were defending the burrows against other questing suitors is not indicated. Nor is there any guarantee that all the females in a burrow would be impregnated by a single male, as mating probably takes place after the winter groups are broken up. Despite this, the association of one male with many females during the period just before mating may be an indication of a polygamous habit. Seton (1929) says, "In a wild state, the skunk is fre-



A typical skunk track.

On guard!



quently found to be monogamous, though probably often polygamous. But on the fur ranch, it is customary to give 3 or 4 females to one male. Some ranchers say that one male will serve a dozen females." Hamilton (1937) states, "The males are probably polygamous and travel widely during this season."

Table 4 summarizes the data that were obtained from the autopsies of 36 female skunks during late winter and spring of 1935,[5] 1936 and 1937. The condition of the genitalia of animals in "heat" has not been studied in this investigation. However, if an enlarged and turgid uterus is indicative of such a stage in the oestral cycle, the two skunks autopsied on February 26, 1937, were in this condition. Since their weights and measurements indicate that they were almost certainly old animals, this is in agreement with Seton's statement of the early heat period in mature females. On a basis of size, nearly all the skunks autopsied from then until April 17 were young individuals. No pregnant animals were found until April 2, when two skunks with very small embryos were taken. From their sizes they were very likely juveniles of the summer before. Again this is in agreement with the suggestion of Seton that young of the last season probably come into heat (and hence breed) in mid-March. On April 17 two animals were taken that appear definitely to illustrate a difference in breeding date between young and old females. The animal that weighed 2,098 grams (4 lbs. 10 oz.) and was 576 millimeters long can without doubt be called an old female. The female weighing 1,120 grams (2 lbs. 7.4 oz.) was only 530 millimeters in length and was, with almost equal certainty, a yearling. These two animals contained 7 and 5 embryos respectively. The length of an average specimen from the old female was 55 millimeters, while those from the young animal measured only 22 millimeters. The relative sizes of the two are not well expressed by the standard embryo measurement (length from end to end regardless of curvature) as the weights of the preserved specimens were 13.5 and 1.1 grams, respectively. Due to a lack of material of known age, estimates are subject to considerable error; but it is evident that the embryos of the young skunk were begotten sometime near April 1, and those of the old animal may well have been a month older. According to this group of records there were apparently two principal breeding periods: one in late February and the other in late March. Most of the embryos taken from April 20 to May 9 probably date from the earlier period, and the females are mostly old animals. Although the young skunks in this series bred considerably later than the old females, that is not always the case. Wight (1931) made very detailed observations on a young captive female that became receptive and mated on March 1.

The autopsy on April 30 gave the latest breeding record obtained in this work. The animal was large, but considerably emaciated. It is to be noted also that this skunk had only three embryos, the smallest number observed. It is possible that it was affected with some organic disorder.

[5] Preliminary work was being done during this year under an assistantship in zoology at the Kellogg Bird Sanctuary.

TABLE 4

AUTOPSY RECORDS ON FEMALE SKUNKS DURING THREE BREEDING SEASONS

Date	Female		Young		Evidence Condition of female
	Length (millimeters)	Weight (grams)	Number	Size (millimeters)	
2- 3-37	512	964	—	—	Not pregnant
2- 4-37	—	1,077	—	—	Not pregnant
2-20-37	557	1,134	—	—	Not pregnant
2-21-37	580	1,318	—	—	Not pregnant
2-22-37	569	1,290	—	—	Not pregnant
2-26-37	581	1,644	—	—	Uterus swollen[1]
2-26-37	593	1,616	—	—	Uterus swollen[1]
2-28-37	552	1,474	—	—	Not pregnant
3- 3-37	512	1,148	—	—	Not pregnant
3- 3-37	535	978	—	—	Not pregnant
3- 3-37	517	978	—	—	Not pregnant
3- 6-37	518	950	—	—	Not pregnant
3- 8-37	559	1,106	—	—	Not pregnant
3-10-37	545	1,049	—	—	Not pregnant
3-14-37	594	1,304	—	—	Not pregnant
3-19-37	562	1,247	—	—	Not pregnant
3-20-35	—	—	—	—	Uterus swollen[1]
3-22-37	526	1,106	—	—	Not pregnant
4- 2-37	525	1,191	5	4	Embryos
4- 2-37	538	1,134	6	3.3	Embryos
4-13-37	—	1,261	4	21	Embryos
4-17-36	—	1,474	5[2]	33	Embryos
4-17-37	576	2,098	7	55	Embryos
4-17-37	530	1,120	5	22	Embryos
4-20-37	—	1,843	6	41	Embryos
4-24-37	567	1,658	7	48	Embryos
4-25-37	578	—	6	63	Embryos
4-26-36	—	1,843	8	58	Embryos
4-26-37	541	1,432	5	73	Embryos
4-28-35	—	—	7	76	Embryos
4-28-36	—	1,417	—	—	Lactating
4-30-37	582	1,191	3	12	Embryos
5- 5-35	—	—	6	73	Embryos
5- 5-35	—	—	7	69	Embryos
5- 8-35	560	1,786	5	71	Embryos
5- 9-35	—	—	6	81[3]	Embryos (1 born)

Average number of young in 17 litters *in utero*—5.76

[1] Uterus enlarged and considerably more turgid than in average individual. This may indicate a condition of "heat."

[2] One small embryo (not counted) measuring 5.5 mm. was evidently being resorbed.

[3] This measurement was made in a curved position as with embryos. The specimen had just been born and was still alive.

Parturition. From these records it appears that most of the young of mature females would be born during the first half of May. The young of first year females which bred in late March or early April would be born in late May or early June. Some animals, however, evidently bred at intermediate times, and the very late breeder of April 30, 1937, probably would not have borne its young until mid or late June.

In these 17 litters of unborn skunks the average number of young was 5.76.

In this small series it will be seen that the smaller (taken to be the younger) skunks tended to have fewer young and the larger broods belonged to females that could definitely be classed as old animals. An exception appears to be one of the females taken on April 2, 1937, which, though probably a young animal, contained six embryos. It is known that the number of embryos found in some mammals averages larger than the number of young born. In an autopsy on April 17, 1936, an embryo was found that was evidently being resorbed. The largest litter noted in this study was eight and the smallest three.

On May 9, 1935, a female skunk was taken in a steel trap on a section adjoining the Kellogg Farm. When found in early morning, the animal had borne one young which was alive and squeaking on the ground. An autopsy disclosed five more young in the uterus. This birth might be regarded as abortive, but I believe that the unborn young had either reached their term or were very close to it. The young animal that was born weighed 34 grams. Measured in the curved position (for comparison with embryos) it was 81 millimeters long. Measured in the conventional manner for adult animals its length was 120.5, the tail was 38, the hind foot 15, and the very rudimentary ear about 4 millimeters. This specimen (a male) was covered with a sparse growth of hair one-fourth inch in length. The hair and skin were pigmented, appearing dark gray everywhere except in the region of the stripe and the tip of the tail, which were conspicuously white. The eyes were tightly closed and the ears were thick, fleshy, and turned down over the position of the auditory orifice which was, in the newborn animal, imperforate. The umbilical cord was dried and frayed about an inch from the body. The small creature was jerking actively about on the ground and its birth may have been normal.

Lactation and Family Life. Seton (1929) states that in the wild, young skunks do not wander far from the den so long as they are depending on the mother's milk. In midsummer they begin to eat solid food and to make nocturnal excursions with the mother.

On an evening late in June, 1936, an adult skunk (doubtless a female) was seen with five small young in the poultry yard at the Kellogg Farm. A few nights later another female was observed with four kits in the same locality. Early in June an old skunk and three young were seen at dusk on the sanctuary. Other reports indicate that it is common in this locality for old skunks to be abroad at night with their young by late June or early July. Several well-grown young were captured in box traps in the poultry yard on July 17, 1936 (Table 3). These animals had been attracted by lumps of canned mackerel tied in cheese cloth, which were eaten in every case. The teeth and scent defense of the smallest of these juveniles were observed to be very well developed. Eight young removed from the traps on the morning of July 18, were marked and liberated in a stump pile 300 yards west of where they were trapped. Two days later one of them was retaken in the poultry yard. On July 23 another was caught. Both of these animals were moved back to the stumps and liberated, and

each was again trapped in the chicken range. One of the other marked juveniles was retaken twice here (July 25 and 27) after being removed to the stump pile.

It is evident that these young skunks were capable of living independently of the mother by July 17. The teeth were well developed, and the animals appeared too large and vigorous to have been nourished solely by nursing a 4-pound mother. From their appearance and behavior, it is probable that in this locality young born in early May are weaned by July.

There is little good evidence from the present study as to how long skunk families normally remain together. On two occasions what appeared to be young individuals were seen alone at night during August. Cuyler (1924) says of the striped skunk, that the family remain together until fall, when they disperse. Several other authors have stated, however, that the young den up with the mother and do not separate until late winter (Merriam 1886, Lantz 1923, Nelson 1918, Louisiana Department of Conservation 1931). Brayton (1882) says that the animals found in dens together are not necessarily members of the same family. From the several records on skunks in dens (p. 218) it appears that on this area the large groups found in winter were not families, but inactive females, usually with a male who may, perhaps, keep out other males. As considerable numbers of young females were present in such aggregations, if the animals had not been sexed, they might have been mistaken for family groups. From inference, then, the families are broken up by fall; although in other localities the habit may be different.

DENS

In this region skunks do not attain a very profound state of torpor in the winter dens. Thus they cannot be said to hibernate in the same sense as the woodchuck and the spermophile. The skunks which I have taken from burrows in midwinter appeared very drowsy and lethargic, although they were sufficiently active to resist being removed from their tunnels. The sudden awakening did not markedly disturb them however, as a few minutes after ten females had been placed in a bag they were rolled up in a comfortable heap and sleeping soundly.

On this area skunks have been found in stump piles and dumps and under buildings. Their usual habitation, however, appears to be a burrow dug by themselves or another species (Kennicott 1858, Goodwin 1935, Johnson 1930). Skunk burrows are usually 10 to 15 feet in length and extend from 1 to 3 feet below the surface. An enlarged chamber at the end or elsewhere along the tunnel contains a nest of leaves or grass. (See also DeKay 1842, Audubon and Bachman 1849, Brayton 1882, Selko 1938b, Seton 1929.) Of 26 burrows excavated on, and in the vicinity of, the Kellogg Farm in January, February, and March, 1937, all but two had more than one opening. In two cases the only extra opening was a narrow passage too small for a skunk to use but which would serve for ventilation. Usually there was a main tunnel slanting downward at an easy slope for 6 to 10 feet, at the bottom of which was a nest of leaves or grass. The largest nest found contained about a bushel of such material. Usually at least one other tunnel connected with

the nest chamber and as many as five openings to a den were found. Most of the nests were about two feet below the surface. The deepest was in the side of a hill and at the end was 5 feet in vertical depth.

On two occasions skunk habitations were found with heaps of droppings near the burrow mouth. In one of these instances a large handful of scats was piled in a small cavity dug in the ground. In the other a large double handful of droppings was piled beneath a small honeysuckle bush about 10 feet from the burrow. These two skunks had evidently made an effort at sanitation. In other cases scats were found within the burrow.

During October the skunks apparently were preparing their burrows for winter. Frequently during this month dens were found with fresh nesting material stuffed into or scattered about the openings (see also Selko 1938a), and one animal was observed engaged in den refurbishing. A skunk burrow was located under the foundation of my cottage directly below the first-floor bedroom window. During the night of October 17, 1935, I was awakened by a noise, and upon looking out the window saw a large star skunk[6] just a few feet away. It was busily gathering nesting material.[7] It would start about 10 feet from the house and scratch together a bunch of dry leaves and grass with its front paws. It then backed toward the house, scraping the material along beneath its belly with its front feet. The debris was piled into the burrow entrance and then, although the animal was nearly out of sight, it appeared to turn and push the leaves ahead of it down the burrow. The crunching of the leaves under the foundation was audible long after the skunk had disappeared. The animal continued this work from 2:50 until 4:20 a.m., after which it remained within the burrow. On the following morning the hole was found plugged with a ball of leaves and grass. Another burrow with a similar plug was found soon afterwards.

[6] A skunk without stripes but with a white spot on the back of the head.

[7] F. F. Tubbs made similar observations at this same burrow during October, 1934.

INDIVIDUAL RANGE

Trapping for short periods in the sections immediately to the south and to the northwest of the Kellogg place showed that some skunks marked on the farm were ranging over these and doubtless other adjacent territories. Seton (1929) gives a half-mile radius as the probable range of individual skunks. The few records from the Kellogg Farm tend to support this conclusion, a mile being the extreme limits of the known range of any of the individuals handled. However, a single night's wandering, although it might extend well over a mile, often lay entirely within a quarter- or a half-section of land. It appeared common for a skunk to wander more widely over a period of time. Several individuals were taken at points between three-quarters and a mile apart. However, as most of this study was carried on within a radius of half a mile, and repeats on individuals were few, the available information is not reliably indicative of the extremes of range.

The most satisfactory check on a skunk's movements was obtained during a short period in the winter of 1937. On January 28, skunk number 58♂ was

dug out of a burrow just north of Wintergreen Lake. On February 16 this animal was found a quarter of a mile to the west in a burrow with another male skunk and an opossum. The den was reconditioned and the animals returned to it. On the following day this same animal was found in another burrow that was opened three-quarters of a mile to the northwest. This skunk had moved at least a mile in 20 days and over three-quarters of a mile in one night, but its movements may not have been normal due to the disturbances to which it had been subjected. The fact that the trapping took 96 individuals on this 500 acres in two years and that the largest number of repeats for any one individual was 6 would indicate that many of the animals were not to any great extent confined to the area. In support of this also is the fact that, in spite of the small amount of work that was done on adjacent areas, eight skunks were taken that were marked on the farm.

SKUNK CHARACTERISTICS

Scent and Cleanliness. Contrary to popular belief skunks are ordinarily almost odorless. On numerous occasions I have held a live skunk to my face without being able to perceive any of the characteristic smell given off when the scent glands are discharged. Neither is there normally any of this odor about the dens. It has been found in handling that if the tail is pulled up along the belly so that the anal opening is covered, a skunk will retain its scent. Apparently these animals avoid contact with the oily fluid as much as possible. Audubon and Bachman (1849), Stone and Cram (1920), and Bailey (1936) have described these characteristics of skunks.

Voice. Skunks are ordinarily silent. Just two types of sound have been heard uttered by the animals during this study. Several times when skunks were encountered at night, a sound resembling the bark of a fox squirrel was heard. An evidently similar noise has been attributed by Cuyler (1924) to the striped skunk. In the present work skunks sometimes growled when handled. This was most often true of males. Both "churring" and growling have been described by Seton for the Hudsonian skunk. Evidently the voice is similar in at least these three races.

Running. When a skunk was liberated from a box trap we usually followed it to learn the location of the burrow that it entered. Several times an individual was followed to the same hole. One such animal, a young female, was living in a tile drain under the paved road leading to the sanctuary gate and, when liberated from a trap, would run directly down the road to the tile. Twice I followed this skunk to its den, running a few feet behind it. The utmost speed that it appeared capable of was a fast trot for me. If pressed too closely the animal would raise its tail over its back and, in full stride, take a sidewise try at me with the scent glands. When this was unavailing it would stop and stamp its front feet, with tail held high over its back (Plate 10), before continuing the dash for safety.

Temperament. Certain skunks handled in this project displayed marked individuality. Old males were particularly likely to bite and make trouble. Young skunks were much less difficult to deal with, and females were usually

easily handled. Some of the females were very docile and, though handled several times, never soiled a bag. A few, however, were extremely nervous and would discharge when the trap was approached. As compared with the other species studied skunks were very tame and sanguine, with none of the wildness of rabbits, cats, or weasels.

Flesh and Fur. Several of the earlier writers mention the fact that skunks were regularly eaten by the Indians (Richardson 1829, Audubon and Bachman 1849, Seton 1909), and numerous authors have from personal experience or hearsay indicated that the flesh of this animal is well flavored and tender (Kennicott 1858, Merriam 1886, Cory 1912, Stone and Cram 1920, Cuyler 1924). I have tried it and found it very good. An old male, after being steamed and well browned in a skillet, was not at all tough and had a very pleasing flavor. The main objection to the creature for eating purposes is that, as compared with a rabbit, there is little meat on it.

As a fur animal the skunk has become of considerable importance and its value for this purpose is widely accepted as a reason for tolerating the species. If the truth were known, however, the fur produced by the skunk in Michigan is probably of less value than the crops that are saved for the farmer by this animal's destruction of harmful rodents and insects (Allen 1937). That skunk fur was not always appreciated to the extent that it is now is shown by a statement of De Kay (1842), "His fur is coarse, and of no value as an article of commerce." On this point Kennicott (1858) says, "The American and Hudson's Bay fur traders buy the skins in considerable numbers, which are manufactured into various articles of wearing apparel, though, it is almost needless to say, such furs are sold under a fictitious name." Evidently fur standards have undergone some evolution in the last 100 years.

MANAGEMENT

Based upon the number of females occupying burrows on the area and a postulated sex ratio of 50 percent females, a resident winter population of approximately 46 skunks was calculated for the Kellogg Farm in the winter of 1936–37 (Allen 1938). Twenty females were found in two burrows. Obviously if a trapper had dug out these burrows and killed the animals for fur, a large part of the breeding stock of the following year would have been destroyed. That these winter aggregations are not unknown to trappers has been revealed in numerous conversations with farmers and fur-buyers. George E. McDonald of Martin in Allegan County, tells me that about 1918 he tracked a skunk to a den and, upon opening the burrow, removed 18 skunks which he killed and sold for fur. This is the largest winter group that has been reported to me, although 8 or 10 are not uncommon. Some of the trappers deprecated the practice of digging out burrows, on the ground that it takes too many skunks. However, only one, a fur-buyer, was aware that a high percentage of the animals so taken are females. Most trappers do not bother to sex the animals and have no idea as to the sex ratio in their catch. In the present investigation it was demonstrated that most female skunks on the Kellogg Farm became inactive early in December, but that a few males (usually old animals)

were active until the middle of January in 1936 and at intervals all winter in the milder season of 1937. These facts accounted for the unbalanced sex ratio of 20 males to 10 females handled in the first fall and winter. Apparently the females were holed up during most of the season while many of the males were making periodic sorties above ground in search of food, or perhaps of a den full of unsponsored females. Hamilton (1937) sexed a series of skunks taken by trappers in New York state and found a very definite difference in the activity of the two sexes. In the winter of 1931–32 female skunks became largely inactive in early December, and in 1933–34 most females were inactive by the middle of November. The author found that holing up was correlated directly with descending temperature. During both winters, however, numbers of male skunks were active until mid-January. Hamilton's demonstration of a 13.8 per cent loss of weight over the winter period among males as compared with 38.0 per cent loss in females lends credence to the supposition that the former may feed occasionally during this period, while the latter are completely inactive in the dens. The point of interest is that trapping above ground during December and January evidently takes a marked preponderance of males. William Parks of Augusta, Michigan tells me that of the skunks that he buys late in the season not more than one-fifth are females and that some of these are probably dug from burrows.

From the evidence here cited, it appears that selective harvesting of male skunks is entirely possible. If the catch is limited to animals taken above ground in steel traps after December 1, a low percentage of females is to be expected. As the species is probably polygamous, a fairly large catch of males should be possible without greatly impairing the productivity of the spring breeding stock.

From the same evidence, where fur is the main consideration, the digging out of the winter burrows of skunks may be regarded as a destructive practice. For by this method concentrations of females will be discovered and killed, thus eliminating breeders required to produce a new generation. However, on areas where other values make it desirable to reduce the numbers of this animal the method is probably the most economical that could be employed.

SUMMARY

In a Michigan study of the eastern skunk, 143 individuals were handled by box trapping, steel trapping, and the digging out of winter burrows. The average weight in a late winter series of 33 male skunks was 1,905.1 grams. Thirty females taken during the same period averaged 1,411.8 grams. A total of 36 females were autopsied during the breeding season. The findings indicated that the older females bred in late February and young females about a month later. During the winter old animals could usually be separated from juveniles of the year on the basis of weight. The trapping of young skunks showed that most juveniles in this region are probably weaned by July. The families apparently are broken up before the winter hibernation groups are formed. Twenty-six winter burrows were excavated and 11 contained skunks. In each of two burrows one male skunk was

found with 10 females. In no case was more than one male present with females. Female skunks were found to become inactive in winter earlier than males; hence trapping late in the season will take mostly males and preserve the females as breeders. Conversely, the digging out of winter dens will take a high percentage of females and destroy the source of a possible new crop.

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THE EVOLUTION OF PREDATOR CONTROL POLICY IN THE NATIONAL PARKS

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The policy of protecting all predatory animals in the national parks of the United States has resulted from decades of practical experience. The first national park, Yellowstone, was established in 1872. One of the objectives was complete protection of wildlife, but there was seldom any effort to apply this guardianship to the larger carnivores. Since the primary objects of concern were the hoofed mammals, especially the deer, antelope, and bighorn, their enemies were killed. However, as conditions and public sentiment changed, doubts of the necessity of stringent predator control arose. With increasing perception of the interrelationships of animals, the policy of control was greatly modified until, today, predator control is rarely employed and then only to prevent extirpation of vanishing prey species.

The history of predator control in the parks holds much of value for the ecologist who is interested in the evolution of opinion on animal relationships. Whether based on research or current belief, predator management has been greatly influenced by superficial observation, personal bias, exigencies of the occasion, and group pressures. Control methods have varied, tending of late decades toward those of greater selectivity. Even the species included in official lists of predators have varied. Numerous at first, these became fewer with the passing years particularly by exclusion of the smaller carnivores.

In this account, Yellowstone National Park instances must frequently serve to illustrate policies and events. Not only was that park established long before any others, but the available early records for it are far more complete. In considering information from all of the early records, however, it must be remembered that they were frequently based upon random observation, personal belief or hearsay, and were rarely made by trained biologists.

For the first six years of Yellowstone's existence, the failure of Congress to appropriate funds for administration prevented the Superintendent, N. P. Langford, from living in the area or doing anything for its maintenance. During this period, poaching hunters and trappers pursued their turbulent course of extracting personal sustenance and profit from the wildlife.

In 1878, however, an appropriation for administration was made and P. W. Norris went to Yellowstone as resident Superintendent. Like all frontiersmen and wilderness sojourners of their day, the early superintendents exercised sporadic and haphazard control of wolves, cougars, and other carnivores. Self-protection and guarding of personal possessions, as food supplies, had been the original objective. Occasionally a predator was shot to prevent it from killing game, the actuating motive being to save the future food "on the hoof" or to prevent the "cruelty" attributed by the human mind to destruction of prey by the predator.

In his report for 1879, Norris de-

scribes killing an especially large mountain lion during the night to prevent it from molesting the riding and pack stock. Later, an exceptionally fine grizzly that had killed a horse was shot over bait composed of two bull elk, which had been killed for the express purpose of luring the bear within range. A pair of martens that were found feeding on the remains of the elk carcasses also were killed. Two years later he described the "sudden terribly sharp and prolonged screams" of the cougars as being the cause of false Indian alarms and stock stampedes. This led to persistent efforts to exterminate the big cats, with some degree of success.

Protection of the ungulates rapidly became of greater importance as a motive for predator control. Under better protection from poachers, the "game" increased and in spite of "control," the carnivores followed suit. By 1889, Acting Superintendent F. A. Boutelle, Captain First Cavalry, recorded his belief that something should be done to exterminate them. The next year he was more than ever convinced that the bear and cougar were doing a great deal of mischief and should be reduced in numbers. In the park report for 1897 appeared the first observation of the detrimental effect of coyotes on antelopes. Almost without interruption down to very recent years, the successive administrative officers of this park have reiterated the belief that coyote control must be continued in order to save the antelope from extinction. Other "game" species, too, were objects of solicitous concern. In 1897, Lieut. Elmer Lindsley, in a report on fish and game to the Acting Superintendent, stated that coyotes were doing some damage to the waterfowl and had killed some of the elk fawns. He concluded that if a large number of coyotes could be eliminated, it would doubtless be a great benefit to the other game in the park. The 1899 report states that mountain lions were numerous and destroyed much game and that several were accordingly killed on the mountain sheep range. For some years, nevertheless, a large number of predators continued to be in evidence. In 1904 Major John Pitcher, Acting Superintendent, wrote that mountain lions, formerly not abundant, had become quite common although rarely seen. According to him they preyed chiefly upon the elk but were also very destructive to deer and mountain sheep. Although the first-named two prey species were so abundant that the number killed could be spared, the bighorns were said to be dangerously near extinction. Successive reports continued to repeat estimates of large numbers of predators and to urge the necessity for their control or extermination for the protection of "game." However, around the opening of the 20th century the list of harmful species was greatly restricted, to include usually only the wolf, coyote, and cougar.

Reduction of the number of species classified as destructive predators evidently lasted until the close of administration of the parks by the Army. In 1916 the National Park Service was established and took charge. Immediately, the reports began to express great concern for the safety of the grazing and browsing mammals. Predator control was practiced with thoroughness, and the list of undesirable species increased to include not only the cougar,

wolf, and coyote, but also lynx, bobcat, red, gray and swift foxes, badger, mink, weasel, fisher, otter, and marten. Even pelicans were reduced in numbers in Yellowstone on the grounds of trout protection. All of these species were hunted for almost a decade, the intensity of the campaigns being determined largely by the individual park superintendents. At the Superintendents' Conference in 1925, the marten was definitely eliminated from the proscribed list. Director Mather at the same time stated his opinion that the "black-list" should be reduced to include only the wolf, coyote, and mountain lion. Except in isolated instances, destruction of the smaller carnivores ceased at that time and campaigns against the other species became less intense or were discontinued in most of the parks.

The value or necessity of killing off the predators was rarely questioned during the early history of Yellowstone administration. In 1887 and 1888, however, Captain Moses Harris of the First Cavalry, who was acting as superintendent, apparently observed to the letter the legislation giving protection to all wildlife. In his report for '87, seemingly in answer to criticism of his protection policy, he said: "I have heard considerable anxiety expressed by those who profess interest in the Park lest the rule which protects equally all animals in the Park should work to the detriment of the game proper by causing an undue increase in the carnivora. But while it is true that there are some noxious animals that are not worthy of protection, chief among which is the skunk or polecat (!), yet I am convinced that at the present time more injury would result to the game from the use of firearms or traps in the Park than from any ravages which may be feared from carnivorous animals." The following year Captain Harris again referred to the fears of those who felt the game animals might be exterminated "as without present foundation."

Presumably, the effect of these reports lasted for some time, as the recommendations of Captain Harris' successor in 1889 that special control of predators be authorized were apparently disregarded. Captain George S. Anderson, who acted as superintendent from 1891 through 1896, also held views rather favorable to the carnivores. His annual reports either refrained from mentioning any damage caused by them or referred to the need for killing, and then with obvious reluctance, an occasional marauding bear. In his last report (for 1896) Anderson made the observation, highly unusual for that day, that "the carnivora have increased *and have proved objects of interest to tourists.*" However, in the winter coyotes became so numerous that he "at last felt obliged to order the destruction of some of them, but confined this duty to the authorized scout." Evidently contemptuous of such opinions, however, was Anderson's successor, Col. S. B. M. Young, who described the destruction of antelope, elk calves and broods of grouse by the "numerous and bold" coyotes. He asked and apparently received authority to reduce their numbers, in spite of the feeling of a few friends of the park that extermination of the coyotes would mean eradication of the grass from the winter valley range by the gophers. In general the attitude that predators could do no good determined the administration of con-

trol operations in Yellowstone for the next two decades.

Along with change in control policies, methods of effecting results also pursued a devious course. In early dealings with man's four-footed enemies in the parks, the undesirability of cruel and unusual punishments was forgotten. Norris once described the elimination of a grizzly that had killed a saddle horse, by firing an explosive shell into the bear's chest. Another grizzly, after breaking into a road camp in Yellowstone, was blown up with dynamite previously planted in a pile of garbage utilized as a lure or bait to attract the animal. Such crude methods were abandoned, however, as public sentiment insisted on higher standards, as trial proved their ineffectiveness, or as official regulation decreed.

With growth of the conviction that extensive control of predators would be necessary to insure perpetuation of a desired prey population, shooting of individuals was found to be too slow. Undoubtedly, poison was employed earlier, but the first use recorded was in 1898, when efforts were made in Yellowstone to keep down the numbers of coyotes by poisoning carcasses. The Superintendent reported that to a certain extent this had been successful. The following year he stated that this was the *only* feasible method of control. Poisoning continued intermittently under the army administration not only in Yellowstone but in the other parks. Many coyotes were destroyed in Yosemite Park in the winter of 1910–11 by poison. In order to safeguard the bears this was set out after these animals had gone into hibernation. Poison was successfully used in Glacier Park in 1914 and 1915, strychnine being described as the chief agent. A couple of years later this method was adopted as official by the National Park Service. Apparently prejudice against poison was developing, however, as the last reference to its use discovered in reports is that of 1922 in Rocky Mountain National Park, Colorado. Here it was briefly suggested that a number of predators were poisoned whose carcasses were never found. Because rangers carrying on the work were allowed to keep at least a percentage of the furs, they may have become somewhat reluctant to use a killing method of disadvantage to themselves. Even if recovered, pelts from poisoned animals are of inferior quality and bring lower prices. In 1930 Director Albright stated that the use of poison for predator control was banned from the national parks.

The steel trap was an accepted and widely used means of control of all predators except mountain lions. Trapping was pursued in the older parks from about 1904 and in the others from the date of their establishment. Public sentiment against use of the steel trap developed in the 1920's and in 1928 the Superintendents assembled in annual conference adopted a resolution against its employment. In Sequoia traps had been abandoned since 1920, but the resolution was not put into effect in Grand Canyon until 1930, in Yellowstone 1931, and in Yosemite, 1932.

Trailing with dogs was, of course, restricted almost entirely to cougars. A pack of hounds was procured for Yellowstone National Park in 1893. No records of their use or the results were made until 10 years later, when Major John Pitcher of the Sixth Cavalry, Act-

ing Superintendent, reported that the dogs rendered good service and enabled the game warden and scouts to kill 15 panthers during the winter of 1903–04. By 1908 mountain lions were scarce, only one being killed during the entire year. The pack was, therefore, sold. In 1914, however, dogs were again brought in by a paid hunter and used in killing 19 cougars. Trained hounds were also used in the earlier years of some of the other parks, particularly Sequoia and Yosemite. After the establishment of central administration in 1916, park rangers in Yosemite and Glacier maintained dogs that were used for hunting cougars. On special occasions, packs with their owners, were hired. Acting Superintendent Lindsley of Yellowstone reported in 1918 the hiring of Steve Elkins, the famous guide and mountain-lion hunter, for several weeks with his pack of lion hounds to hunt lions, wolves, and coyotes. Packs of dogs of Biological Survey hunters, upon official request of the Park Service, were used in national park areas, as late as 1928 in Grand Canyon.

Shooting has been probably the most widely used means of predator control, especially in more recent history. It also antedates both poisoning and trapping. In the later years of the nineteenth century it fell into disrepute as a specialized instrument of policy due to the ease with which it could be used against "game" mammals and valuable furbearers by unscrupulous employees or others. Although relatively ineffective as compared with either trapping or poisoning, shooting was carried on fairly consistently because less troublesome. The selectivity of shooting is unequaled, hence as non-selective methods fell into disrepute in the late 1920's, it was stressed to a greater extent. It was the only means of coyote control employed in Yellowstone from 1932 to early 1935, after the steel trap was discontinued.

Casual reference has been made to use of various personnel for controlling predators. Flagrant abuses accompanied this activity under the civilian administration of Yellowstone prior to 1886. Fur-bearers were taken for their hides, and elk, antelope, deer, and bighorn were killed for meat for personal use or enrichment. Opportunities for this illegal killing were practically unlimited for the many persons who were given, or assumed, informal authority to carry fire-arms and use traps on the pretext of killing undesirable animals. Succeeding army administrators found it advisable to confine this duty to the authorized scouts (1896), to the game warden, Harry Yount, and to certain authorized soldiers. As Major Pitcher stated in 1905, "A general permit to kill these animals would have resulted in endless trouble in the matter of protection of other game."

With the establishment of the National Park Service, a ranger force was formed in each park. More permanent and better trained personnel were therefore available soon after 1916 for killing the carnivores and "harmful species of rodents." Special members of the ranger staff were sometimes designated and trained in control work. Inadequate forces and pressure of urgent development work, however, frequently made it necessary to call in outside help. At times, and under new and poorly understood procedures, this was a little informal. For example, Supervisor Ral-

ston of Glacier Park reported in 1916 that many coyotes were killed in the park by settlers. Assistance under more formal and official arrangments was sometimes obtained. Acting Supervisor George E. Goodwin of Glacier National Park reported that during the winter of 1916–1917, a number of mountain lions were killed "by hunters licensed by the service for this purpose."

In his report for the year ending June 30, 1918, Director Mather recorded that a cooperative plan had been worked out with the Chief of the Biological Survey, under which an intensive campaign for the destruction of predatory animals in Glacier National Park was in progress, under the joint direction of the park superintendent and an expert of the Survey. At the same time the latter bureau detailed another hunter to trap and hunt wolves and coyotes along the northern boundary of Yellowstone. At various times other government hunters working under the direction of the Biological Survey carried on predator control in Rocky Mountain, Grand Canyon, Wind Cave, Mesa Verde, Mount Rainier, and Zion National Parks. This cooperative relationship between the two bureaus continued for a number of years until changing sentiment of the late 1920's fostered a policy more favorable to the carnivora.

In general, however, since establishment of the Park Service the ranger staffs of the parks have carried on most of the regular control duties, special hunters being called in only when the administration became alarmed by numerous complaints or kills. Control work was commonly regarded as rather arduous duty, frequently but not always worthy of special compensation. In some cases all of the resulting furs were sold, either in the large fur markets or to operators of park curio stores, and the receipts deposited in the Federal Treasury. In other instances, however, all or part of the furs were turned over to the ranger or hunter taking them. This was especially true prior to about 1922, when game protection through predator control was assigned to the ranger force as a part of their regular duties when so directed. It was believed and hotly argued that, without special reimbursement by at least part of the fur take, the rangers would not pursue control work with sufficient vigor to meet the demands of the situation. In 1925 the Service ruled that employees designated as official hunters were to get not to exceed one-third of the hides secured, the exact percentage to depend on conditions of employment. Certain other employees who were allowed special authority to hunt predators in the parks were still officially permitted to keep all the furs they were able to take.

The intensity of the campaigns carried on against park predators after the reestablishment of civilian control in 1916 would seem to indicate that extermination was desired. The terms "elimination" and "extermination" of coyotes, wolves, and other carnivores were frequently employed in reports and letters of the period 1916–1924. It is probable however, that in many cases the officials concerned used these terms loosely as synonymous with "reduction." Ungulates over much of the United States were numerically low. The orgy of over-shooting, burning, consuming, and wasting had reached

its climax in the early years of the twentieth century. Lack of proper protection and management of the national parks themselves had resulted in decimation of the ungulates even within these so-called sanctuaries. Park officials, given new responsibilities, were impressed with the need for rigid protection of the "game" from any molestation. Carnivores were in disrepute generally and had been for generations. No scientific studies existed of predator-prey relationships. Predator management in the parks followed the general trend and pattern of thought of the times.

In a relatively brief period, however, it made great advance, for while the public and private ideal apparently was complete extermination, park policy, constantly reiterated, was simply one of control. In the first annual report of the National Park Service, that for 1917, the Acting Director stated: "The killing of wild animals, except predatory animals when absolutely necessary, is strictly forbidden in Yellowstone National Park by law." The Superintendent of the same area, in his reports for 1919 and 1920, referred to efforts to keep carnivorous animals down to "a reasonable number." The report of Glacier National Park for 1924 states that mountain lions were extremely rare and adds "It is doubtful whether further hunting should be done until their numbers appear to increase." The superintendents in 1925 definitely restricted the term "predator" to include only wolves, coyotes, and cougars. In his report for the year ending with June 30, 1926, Director Mather stated that "it is contrary to the policy of the Service to exterminate any species native to a park area" but expressed the necessity for some control in order that the weaker animals would not suffer unduly. Col. C. G. Thomson, Superintendent of Crater Lake National Park, in 1927, wrote: "Whenever these (wolf, coyote, cougar) or other predatory animals become numerous they are decimated by Park Rangers and special hunters, but they have a definite place in the balance of nature and I would be sorry indeed if mine were the hand that exterminated the last specimen."

In 1928 the scientific viewpoint on predator control was presented to a conference of superintendents by Dr. Joseph Grinnell, Director of the Museum of Vertebrate Zoology, University of California. Knowledge of predators and their place in the fauna was growing and recognition of their value was hastened by numerous scientific societies and individuals. During 1929 and 1930 the National Park Service was the recipient of numerous resolutions and letters condemning predator control without adequate justification based upon scientific investigation. Among the organizations insisting upon this course were the American Society of Mammalogists, the Wilson Ornithological Club, Cooper Ornithological Club, New York Zoological Society, and the Boone and Crockett Club. Concurrence with this point of view was expressed in replies by Director H. M. Albright. The Service was placed on record by Mr. Albright's statement in the May 1931 number of the *Journal of Mammalogy*, pp. 185–186 as follows:

> The National Park Service believes that predatory animals have a real place in nature, and that all animal life should be kept inviolate within the parks. As a conse-

quence, the general policies relative to predatory animals are as follows:

1. Predatory animals are to be considered as an integral part of the wild life protected within national parks, and no widespread campaigns of destruction are to be countenanced. The only control practiced is that of shooting coyotes or other predators when they are actually found making serious inroads upon herds of game or other animals needing special protection.

2. No permits for trapping within the borders of a park are allowed. A resolution opposing the use of steel traps within a park was passed several years ago by the superintendents at their annual meeting, and they are used now only in emergencies.

3. Poison is believed to be a non-selective form of control and is banned from the national parks except where used by Park Service officials in warfare against rodents in settled portions of a park, or in case of emergency.

All superintendents and custodians were notified shortly after that this statement defined the official policy of the Service.

Meanwhile, through the generosity and interest of the late George M. Wright, the Wildlife Survey of the parks was begun. A notable contribution of this Survey was the issuance, in Fauna of the National Parks, No. 1, of a "Suggested National-Park Policy for the Vertebrates."The portions relating to predators are as follows:

Every species shall be left to carry on its struggle for existence unaided, as being to its greatest ultimate good, unless there is real cause to believe that it will perish if unassisted.

The rare predators shall be considered special charges of the national parks in proportion that they are persecuted everywhere else.

No native predator shall be destroyed on account of its normal utilization of any other park animal, excepting if that animal is in immediate danger of extermination, and then only if the predator is not itself a vanishing form.

Species predatory upon fish shall be allowed to continue in normal numbers and to share normally in the benefits of fish culture.

This policy has ever since been followed and has been published as official policy in "National Park Supplement to Planning and Civic Comment," Vol. 2, No. 4, Oct.–Dec., 1936. Economic interests have been assured that, when necessary, individual predators would be eliminated to prevent unreasonable losses to livestock and other property outside the parks.

Numerous attacks have been made upon this policy and are still being made. Charges of damage by park predators have been usually greatly exaggerated and frequently absurd. Scientific studies by competent observers have been authorized when preliminary observations indicated that more exact work was needed to settle doubts. Thus Bond investigated the effects of coyotes of the Modoc Lava Beds on waterfowl of a nearby refuge; Murie has completed a study of the relationships of coyotes to ungulates and other prey species in the northern part of Yellowstone National Park and is working on the wolf-Dall sheep situation at Mount McKinley. Results of the studies brought to conclusion indicate that control at present on the areas concerned is not desirable. Rather, on the contrary, coyotes under present circumstances are exercising a beneficial influence by removing diseased and crippled waterfowl and surplus prey mammals. It is to be hoped that this policy will be continued and that no control of park carnivora will be exercised until its necessity if proved by

factual data gathered by competent observers.

SUMMARY

It is evident that the national park predator policy in its various stages of development over the past 67 years has, on the whole, reflected the most advanced thought on the subject. Changes have been necessitated by special legal or natural limitations, and effected also by public sentiment and facts brought to light by scientific inquiry. Unfortunately the rapid recovery of hoofed mammals following near-extermination early in the twentieth century was but imperfectly perceived and predators were persecuted in the parks for at least a decade after they had become vitally necessary to maintenance of a balance. Our present problems of over-grazed ranges are in considerable measure due to this lag in human perception of cause and effect. A forecast of future trends is brightened by the knowledge that many past difficulties can be avoided by adherence to the policy of basing protection entirely on scientific investigation and ascertained facts.

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MARKING BIRDS BY IMPING FEATHERS

Earl G. Wright

Many methods for marking the feathers of game birds to note their movements have been published, and at the suggestion of Aldo Leopold, I would like to call attention to the old method of imping (or splicing) feathers used by falconers to keep their hawks' flight feathers in good repair. It is possible by this method to replace part of a broken feather with a feather from another bird of the same species so that the splice cannot be detected. If colored feathers are used they will show up well in any part of the tail or wings, best, of course, in centrals or deck feathers of the tail, so that individuals may be easily recognized.

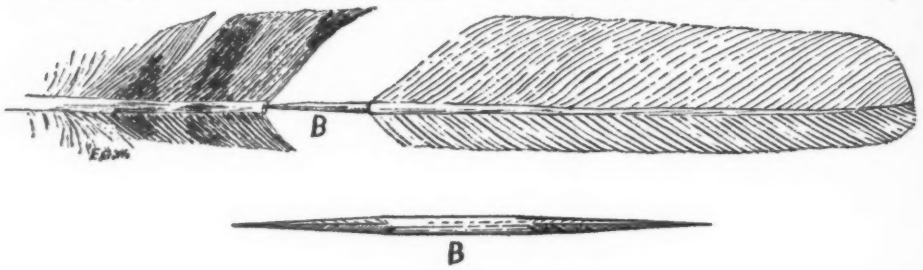

Figure 1

Only strong white feathers, such as the tail and secondaries of white chickens and the wing coverts of white turkeys and geese, should be used for markers. They may be colored with Diamond wool dye to obtain any number of color combinations. For the best results feathers should be thoroughly washed and rinsed, and then rinsed again in vinegar water, then boiled for fifteen minutes in the dye.

The imping needles are easily prepared by grinding ordinary sewing needles on a fine power emery stone. The needle is placed in a pin vise and ground to as long a taper as possible on *three* sides; then reverse the needle and repeat the grinding as illustrated in Figure 1b. The size of the needle will, of course, vary with the size of the feather to be imped.

After the marker feathers are dry, they should be cut to the desired length which should be more than one third of the way down from the quill end, i.e., at a point where the shaft is solid. The species to be marked should be carefully taken into consideration in determining the length of the marker.

Dip the end of the imping needle in tincture of iodine and insert to half its length in the pith of the shaft. The iodine will cause the steel needle to rust and hold firmly; salt brine may be used in place of the iodine. Any number of marker feathers may thus be prepared in the laboratory and placed in envelopes to carry into the field.

Aldo Leopold has described the method of handling the birds for marking in the JOURNAL OF WILDLIFE MAN-

AGEMENT, Vol. 2, No. 1. His method of using a sock as a straight jacket has also been used by falconers for many centuries. An alternative method is to wrap the bird in a cloth, one operator gently holding the wrapped bird, while the other matches the natural feather with one of the previously prepared markers. After noting *exactly* where the natural feather is to be cut, slip a sharp pointed scissors as close as possible to the shaft so as not to disturb the web, and make a clean square cut. Now dip the needle projecting from the marker feather in iodine and push it into the natural feather until the cut shafts meet, making a smooth joint. This method is most easily followed for tail feathers; the wing may also be marked by this method but the feathers must be more carefully chosen as to curve, width, length, and must be right or left hand.

This procedure may sound more difficult than others, but it is in reality quite simple. It in no way impedes the bird, since no additional weight is added, and there is practically no need to place any strain as in some other methods, on either the feather to be imped or any neighboring feathers which reduces the possibility of the bird losing the marked feather.

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MANAGEMENT OF APPLE TREES IN MASSACHUSETTS

Harold M. Bradbury

There is no evidence to show that *Malus coronaria* or any other native American crabapple existed in New England prior to the advent of the white man.[1] The common cultivated apple (*Malus pumila*) came to us from Europe, but it did not originate there. The most authoritative opinion is that it came from the northwestern Himalayas where there are great forests of apples in places where they could hardly have been introduced by man. Apples were brought to Europe in prehistoric times, however, for charred seeds and cores have been found in the remains of the villages of the ancient Swiss Lake dwellers. Prehistoric peoples probably carried the apple all over Europe and Asia. The apple is mentioned, according to U. P. Hedrick ("Systematic Pomology," Macmillan, 1925, page 109), by the earliest writers on agriculture in China, India, Greece, Italy, France, Germany, and England.

The early colonists brought apple seeds and a few trees to North America. The apple found here a congenial home and soon produced innumerable seedlings as it spread out from the colonies. Seeds, scions, and trees went westward with the covered wagons. Johnny Appleseed carried bags of seeds from New England cider mills into the Ohio Valley and planted them in clearings. There must have been many apple planters of less renown.

[1] Appreciation is accorded Professor R. A. Van Meter, Head of the Division of Horticulture, Massachusetts State College, for historical and horticultural data.

Nearly all of our cultivated apples have been selected from these wild seedlings, but recently a few like Cortland have been produced from experimental crosses. The original Baldwin tree was found near Lowell, Massachusetts; the original McIntosh tree grew in Ontario, Canada, and so on.

Following establishment of the apple in this country many wild trees began to appear where seed had been deposited in places favorable to germination and growth until today it is uncommon to traverse a northeastern forest and not find seedling apple trees. Palatability and availability combined have made apple the number one food for wildlife in the northeast. It has, therefore, become an important subject for both research and management.

Bark, twigs, buds, and fruits all are eaten. The cottontail, snowshoe hare, deer, woodchuck, muskrat, fox, mice, grouse, quail, pheasant, crow, grackle, and numerous other mammals and birds feed on apple. The scaly bark is pitted with holes where woodpeckers have sought the sap, and in the spring and early summer the hollow limbs and trunks harbor wildlife broods and litters.

In Massachusetts for many years there has been a law providing for payment, after investigation, for damage caused by wild deer and moose, and it is interesting to note that in 1937 $6,494.04 was paid under this act, at least 90% of which was for deer damage to apple orchards. The records further show that in 1927 $3,215 was paid to an

A (*left*)—Released wild apple tree.
B (*above*)—Increased fruiting and persistency the result of proper releasing.

A (*left*)—*Malus floribunda* ("Bob-white" variety) scion grafted on wild apple tree 1936; bearing fruit, 1939.

B (*right*)—*Malus floribunda* ("Bob-white" variety) parent tree, showing abundance and persistency of the fruit.

1936;

e and

orchardist in Egremont whose plantation was practically ruined by deer browsing. Ruffed grouse have been so active in apple budding that on several occasions legislation has been proposed to authorize the Commonwealth to pay for this form of damage. No such law has ever been enacted, although prior to 1870 these birds were so numerous and so injurious to orchards that officials in some towns paid a bounty on their heads. Such records show that the apple has long been a preferred food of wildlife.

When the Civilian Conservation Corp was first organized in 1933, orders were given to remove all apple trees from the forests, but no sooner had the demolition started when sportsmen and nature lovers deluged those responsible with telegrams, letters, and personal calls, and the order was countermanded. Today in the Massachusetts wildlife program an apple tree is as inviolate as the Washington Elm or the Charter Oak. In June, 1934 a wildlife program was started, and the rest of the year was taken up with the selection and mapping of areas to be managed. Early in 1935 development was begun on the Mt. Wilcox Wildlife Area in the Beartown State Forest at South Lee, Mass. and has continued without interruption. During the five years it has been in progress, much thought and experiment have been given to increasing winter availability of apple fruits.

Complete release and standard pruning were tried on a number of trees (Plate 11, A), and the surrounding ground was grubbed and tilled to supply a mulch. For wildlife purposes this treatment proved too drastic, for although the fruit was improved in size and quality, its holding persistency was impaired, and it dropped early in the fall.

A 75% release was tried on other trees, giving freedom from competition in a variety of exposures. These trees were given a 50% pruning, and the results were similar to those obtained in the 100% release; the fruit was improved in size and quality but fell early.

Fifty per cent releasing (also with different exposures) was followed by a 50% pruning on a few, and in lesser varying degree on other trees, from some of which only dead wood was removed, with the following results: Those trees receiving a 50% pruning bore larger and better fruit, all of which dropped from the tree in October. The trees exposed to the North and East lost their fruit first, and trees given a South and West exposure carried theirs until November. Unpruned trees released to the North and East held fruit until late December, while those exposed to the South and West carried their fruit into February and early March. Holding persistency increased as the amount of pruning decreased (Plate 11, B) the maximum being for entirely unpruned trees; exposure governed in lesser degree.

Some trees were given a 25% release and pruned in varying degrees, but the results were not as satisfactory as those derived from the 50% release. In the 25% release also the less pruning done the better the results.

Trees that are not bearing are grafted with scions of *Malus floribunda* variety "Bob-white." Four hundred of these grafts (Plate 12, A) were made in 1936, and 50% of them are doing well. One of these bore 12 apples in 1937. This crop persisted through the year and was

hanging with the fruit borne in the summer of 1938. The grafts, therefore, can supply a constant food. These small apples are relished by many birds. At the Arnold Arboretum, Boston, fifteen pheasants have been observed feeding on them at one time. Some of the birds ate the apples on the tree while others fed beneath, picking up those which were knocked to the ground by the birds above.

The variety "Bob-white" of *Malus floribunda* originated in a chance seedling at the Arnold Arboretum. The blossoms are pure white and their density so great that they completely hide the tree; the fruit is globose, 6–8 mm. in diameter, and persists until after the following year's crop is borne (Plate 12, B), that is, from fifteen to eighteen months.

Summarizing, we find that for wildlife purposes apple trees should not be pruned because it impairs persistency of the fruit, thus lowering its availability during the snowy season. A 50% release from surrounding shading vegetation with a southerly or westerly exposure gives the required light, yet affords protection from sleet, snow, and blizzards from the north and east. Grubbing out vegetation beneath the tree to remove competitive ground growth and applying from five to ten pounds of high nitrogen fertilizer on top of the ground in a band under the tips of the branches, at about the time growth starts in spring, gives a bumper crop.

Management of wild apple trees should be carried out only in forested or wild areas, never within 500 yards of a commercial orchard. In fact where state-owned land is situated near commercial orchards a good neighbor policy calls for removal of all wild apple trees as a pest control operation.

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RESULTS OF A SUMMER CREEL CENSUS OF LAKES WAUBESA AND KEGONSA, WISCONSIN[1]

David G. Frey, Hubert Pedracine, and Lawrence Vike

Much of the existing creel census literature deals with lakes of small to moderate size, often located at some distance from centers of population. This paper is a report on fishing data collected during the period May 15 to October 15, 1938, from lakes Waubesa and Kegonsa, 2 glacial lakes near Madison, Wisconsin, having areas of 2,034 and 3,145 acres respectively, and maximum depths of 36 and 31 feet. They are connected by a part of the Yahara River 4.1 miles in length. The water entering Waubesa comes from lakes Monona and Mendota, which are part of the same drainage system, and flows south into Kegonsa. Both lakes are strongly eutrophic and usually have heavy blue-green water blooms in summer. Both lakes show a marked midsummer oxygen stratification but only a slight temperature stratification.

Thanks are due the Wisconsin Conservation Department and the Works Progress Administration, who did much to make this census possible. The latter organization supplied 2 men to aid in the census: Hubert Pedracine collected data for Waubesa and Lawrence Vike for Kegonsa. With only 2 men available to help collect the data, it was impossible to contact all the fishermen or obtain complete records of the fish caught. Cards were printed and distributed to the boat liveries and cottages with instructions for their use, the idea being to have one card filled out each time a boat was used. Placards calling attention to the fish census and stating its purpose were displayed conspicuously, and boxes for collecting cards were located in convenient places. Information desired on the cards included number of fishermen, hours spent fishing, and numbers of the various species of fish caught. It would have been unfeasible to request more detailed information; many of the fishermen neglected to fill out completely even the simple cards we used. The cards were collected once or twice a week by the 2 W.P.A. men, who tried to stimulate interest and obtain as much cooperation as possible.

By means of carefully considered estimates it has been possible to arrive at figures for the total number of fish, fishermen, hours, pounds per acre, etc., but unless stated the figures and graphs in this paper are based on the actual data from the census cards.

Trend of Fishing During the Season

(Figure 1)

It is evident that the greater proportion of fish were caught in Kegonsa during the first half of the season, and in Waubesa during the middle of the season; and that for each lake after reaching a maximum, the weekly catches decline quite uniformly. The weeks of Memorial Day and July 4th show an increase in the numbers of fish caught, except for Kegonsa during the week of

[1] From the Limnological Laboratory of the Wisconsin Geological and Natural History Survey and the Zoology Department, University of Wisconsin. Notes and reports No. 91.

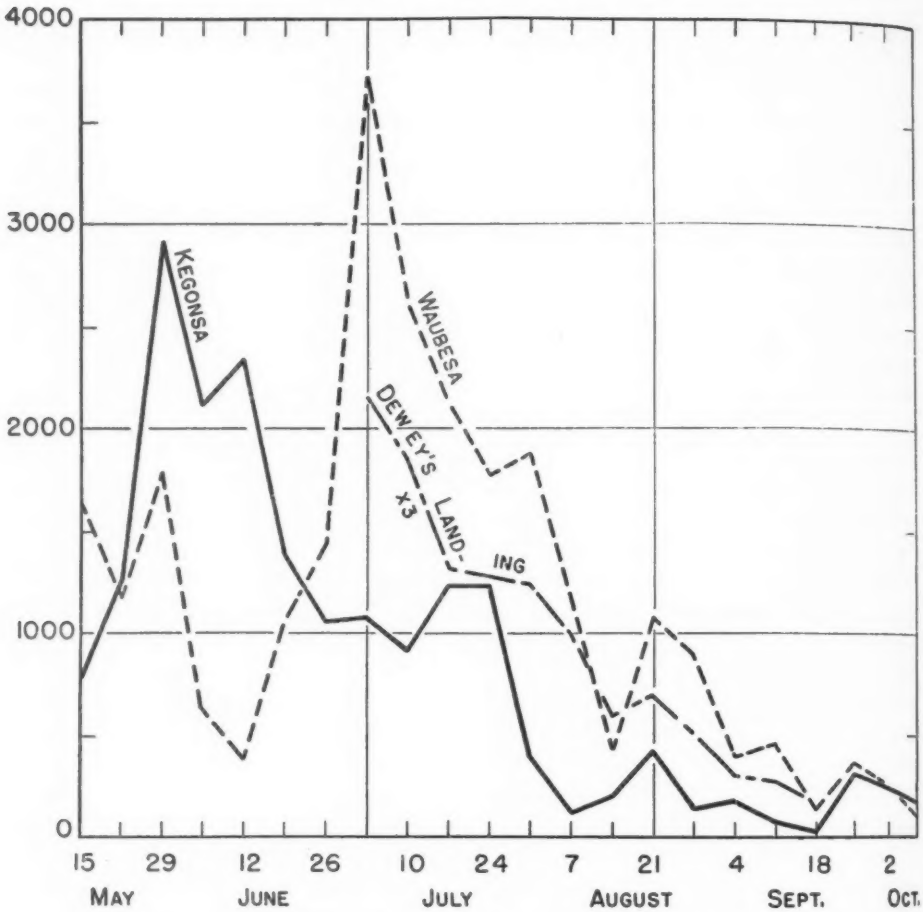

Fig. 1. Fluctuations in weekly catches during the season as shown by the total numbers of fish reported on the census cards. The weekly totals for Dewey's Landing have been multiplied by 3 to facilitate comparison. The dates represent the first day of each week, beginning with the opening of fishing season.

July 4th. This is explained later as being caused by a decline in rate of catching, chiefly of white bass and perch.

It is difficult to determine how much of this record of decline in weekly catches in the second half of the season is caused by actual reduction in fishing effort, and how much by waning of interest in the census. That the latter contributed to the effect there is no doubt. There is reason to believe, however, that it is not so important as might be expected. Plotted also on Figure 1 are the data from Dewey's Landing, one of the boat liveries on Waubesa which gave 100% returns after July 1. The actual figures for this curve have been multiplied by 3 to bring the curves closer together. This more comparable curve shows a similar decline with

peaks and depressions occurring at the same times as those of the total curve. Hence the curves probably give a fairly trustworthy picture of the fishing trend during the season. The curves for fishing effort in hours (Figure 4) follow closely those for the total catches.

QUALITY OF FISHING
(Figure 2)

As to number of fish caught per hour of effort, both lakes were poor at the beginning of the season. Likewise both lakes showed good fishing from mid-June through most of July, and in Waubesa the best fishing of the season came during late June and early July. Fish caught per hour in Waubesa declined steadily through August, rising somewhat during mid-September. Kegonsa had some of its best fishing during late August and early September, but few fishermen were on the lakes at this time. As a general statement, quality of fishing measured by the number of fish caught per hour of effort was uniformly better in Waubesa than in Kegonsa except for brief periods at the beginning of the season and that just mentioned for late August and early September.

Not shown in Figure 2 are the catches for each separate week. These would have indicated that the best fishing of the season in Waubesa occurred during the week of July 4th, an average of 2.42 fish being caught per angler hour. This coincides with and helps explain the maximum weekly catch of the season for Waubesa as shown in Figure 1. In Kegonsa only 1.08 fish were caught per hour of fishing during this week, so that one can say fishing was twice as good in Waubesa as in Kegonsa the week of July 4th.

The season maximum catch for Kegonsa during the week of Memorial Day did not coincide with a week of exceptional fishing, although the number of fish caught per hour did rise slightly; but it was produced instead by a season maximum in intensity of fishing, 1,411.5 fisherman hours being recorded for this week (Figure 4).

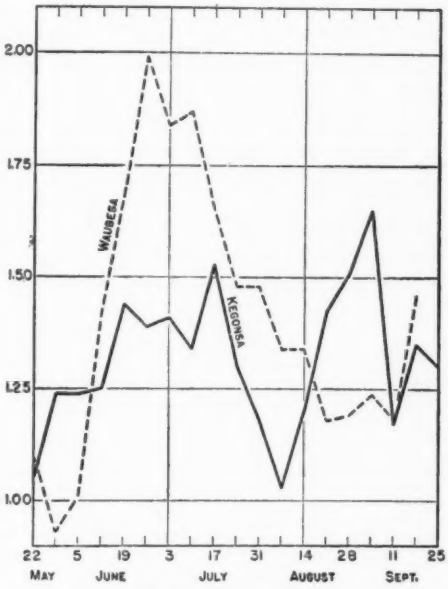

Fig. 2. Variation in catch per hour of effort based on data from cards completely filled out, the curve smoothed by a moving average of 3. The dates represent the first day of each week of the fishing season.

Fishing, measured by numbers of fish caught, quality of fishing, or any other criterion, was definitely better in Waubesa than Kegonsa. Considering only the cards completely filled out, the average number of fish caught per hour of effort was 1.25 for Kegonsa and 1.47 for Waubesa. It was noted that for both lakes the average number of fish per card completely filled out was not the

same as the average number recorded on the incomplete cards, but that the number of fishermen per card for each lake remained the same. It seems reasonable, therefore, to assume that the fisherman day was also the same length for the incomplete cards as the complete cards. Adjusting the estimates for both lakes on this basis, the final figures for fish caught per angler hour are 1.24 for Kegonsa and 1.86 for Waubesa. Each of these figures is probably too high, because all fishermen were careless about handing in cards when fishing was poor or no fish were caught. Eschmeyer (1936), working on Fife Lake in northern Michigan, found that 17 to 50% of the anglers caught no fish. These lakes are not strictly comparable however, because of the greater attention to game fish in Fife Lake. (See also Hazzard and Eschmeyer, 1938.)

SUCCESS OF FISHING FOR INDIVIDUAL SPECIES

(Table 1)

Waubesa excelled in crappie and bluegill fishing and slightly in northern pike fishing; Kegonsa was better for perch, white bass, wall-eyed pike, and a little better for bullheads, small mouth and large mouth black bass. Of all species crappies in Waubesa bit best with an average catch for the season of 1.5 fish per hour of effort. In Kegonsa the fish biting best was the white bass, which was caught at the average rate of 0.6 fish per hour of effort.

There is not much correlation between the 2 lakes as to time of season when each of the 5 major species was taken most frequently.

TABLE 1
CATCH PER 100 FISHERMAN HOURS FOR EACH SPECIES OF FISH IN THE 2 LAKES

Figured on the basis of total fish reported on the cards and hours spent catching these fish.

Species	*Waubesa*	*Kegonsa*
Bluegill	13.9	8.0
Common sunfish	.6	.4
Crappie	150.0	17.2
Rock bass	.3	.2
Perch	3.3	27.1
White bass	9.0	59.4
Small-mouth black bass	.5	.7
Large-mouth black bass	.6	.9
Wall-eyed pike	4.0	6.0
Northern pike	1.6	1.2
Bullhead	1.8	2.4
Carp	.7	.9
Totals	186.0	124.0

Waubesa

1. The catch of crappies started off well during the opening week, dropped to a season minimum during the week of June 12–18, rose sharply to a season maximum during the week of July 3–9, and then continued high although with numerous fluctuations for the rest of the season.

2. The take of bluegills started the season poorly, climbed to a peak (1.38 per hour) during June 19–25, and then dropped to almost nothing after July 31.

3. Success with perch started slowly, reached a mid-season maximum during July, and then dwindled as with the bluegills for the remainder of the season.

4. White bass captures continued throughout the season but with numerous weekly peaks and depressions; the best fishing was in mid-July.

5. Wall-eyed pike fishing was good until the week of June 26, after which it was poor for the rest of the season.

Kegonsa

The census for this lake does not show such clearly defined maxima and minima as does that for Waubesa.

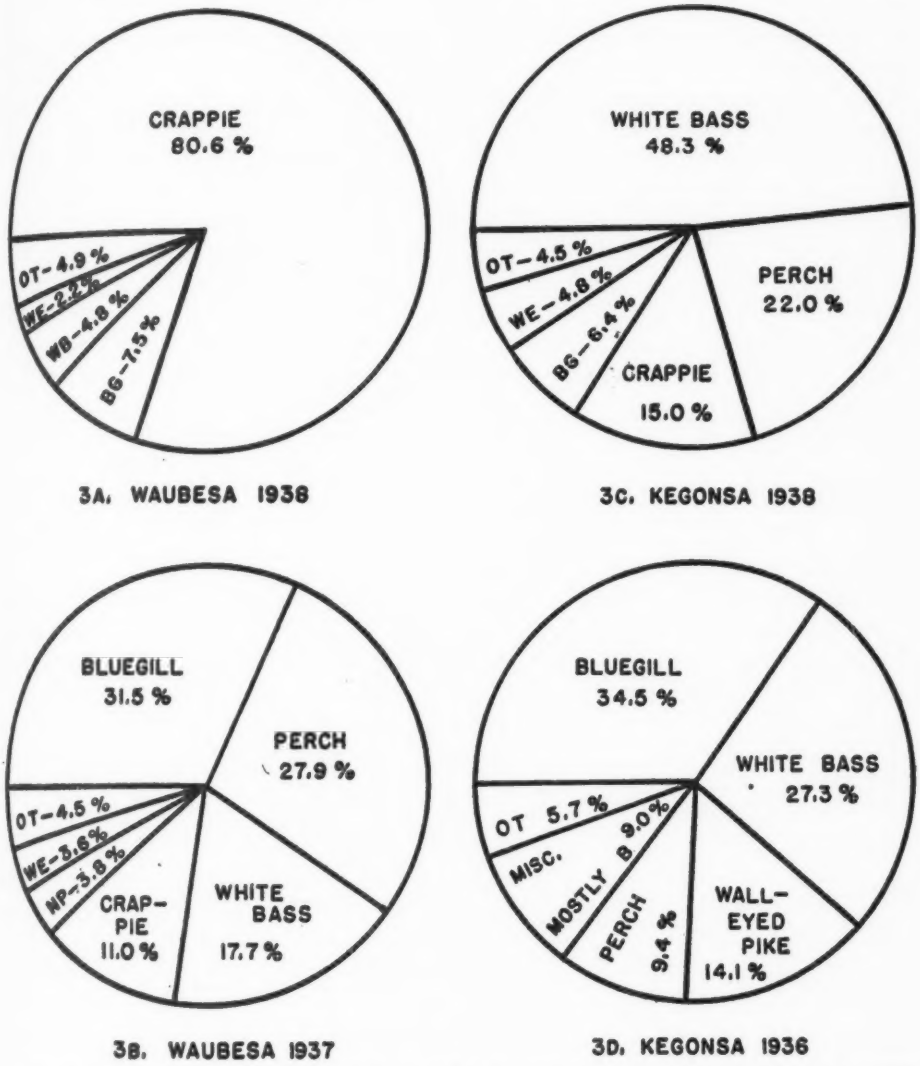

Fig. 3. Percentage composition of the catches from Waubesa and Kegonsa for the 1938 season, and comparisons with percentage compositions for previous censuses of the 2 lakes. 7,746 fish were recorded from Kegonsa in 1936. 64,300 fish were recorded from Waubesa in 1937. Abbreviations: B—Bullhead; BG—Bluegill; WB—White bass; WE—Wall-eyed pike; NP—Northern pike; and OT—All others.

1. The crappie take started the season poorly, reached maxima during July and late August, and minima during early August and middle September.

2. Bluegills behaved much as did those in Waubesa. They bit best during the week of June 19–25, continued well during most of July, and then practically ceased for the rest of the season, al-

though not so completely as in Waubesa.

3. The catch of perch started the season very poorly, climbed steadily to a maximum August 7–13, and continued fair for the rest of the season with the exception of the period August 21 to September 3.

4. White bass fishing started well, dropped to almost nothing from July 31 to August 13, rose to a seasonal maximum August 28 to September 3, and afterwards fell off considerably.

5. Wall-eyed pike fishing also was best during the first half of the season, with the decline in the second half not so pronounced as in Waubesa.

Not enough data were obtained for the other species to warrant any statements about seasonal variations in the rate of catching.

PERCENTAGE COMPOSITION OF THE CATCHES

(Figure 3, a and c)

Each lake has one species which composes 50% or more of the catch. In Kegonsa white bass constituted half of the catch; in Waubesa crappies (almost entirely black crappies) comprised 80% of all fish caught. Gamefish (northern pike, wall-eyed pike, small-mouth and large-mouth black bass) amounted to 3.5% of the total in Waubesa and 6.3% in Kegonsa, indicating a slight supremacy in gamefish for Kegonsa.

NUMBERS AND POUNDS REMOVED

(Table 2)

The first column for each lake shows the actual number of each species of fish recorded on the census cards; the

TABLE 2
ACTUAL NUMBERS OF FISH RECORDED ON CENSUS CARDS, AND ESTIMATED TOTAL NUMBERS AND POUNDS CAUGHT

Species	Waubesa				Kegonsa			
	Actual numbers recorded on cards	% of total catch	Estimated totals based on 34% of the fishing reported	Estimated pounds of fish per species	Actual numbers recorded on cards	% of total catch	Estimated totals based on 41% of the fishing reported	Estimated pounds of fish per species
Bluegill	1,902	7.45	5,600	3,160	1,193	6.43	2,910	1,600
Common sunfish	76	.30	210	60	55	.30	130	40
Crappie	20,576	80.64	60,520	22,700	2,591	14.96	6,320	2,370
Rock bass	40	.16	110	60	24	.13	60	30
Perch	452	1.77	1,330	530	4,085	22.01	9,960	3,950
White bass	1,228	4.81	3,610	2,400	8,955	48.25	21,840	14,430
Small-mouth bass	48	.19	140	300	46	.25	110	240
Large-mouth bass	62	.24	180	400	57	.31	140	310
Wall-eyed pike	554	2.17	1,630	2,700	893	4.81	2,180	3,600
Northern pike	222	.88	620	3,400	176	.95	430	2,370
Bullhead	252	.99	740	330	355	1.91	870	380
Carp	103	.40	300	500	128	.69	310	510
Totals	25,515		74,990	36,540	18,558		45,260	29,830

second columns indicate the percentage composition of the catches—the basis for Figure 3, a and c. In columns 3 are estimates of the total numbers of fish removed from each lake, about 34% of the total Waubesa catch being recorded on the census cards and 41% of the Kegonsa take.

These coverage estimates were arrived at in the following manner. Estimates were made of: (1) the relative proportions of the total fishing done through boat liveries and through other agencies; (2) the percentage of independent fishing that was reported; and (3) the percentage of fishing done through each livery that was reported on the census cards. It was known how many boats each livery had. On the assumption that each livery boat had equal value or effectiveness in fishing, it was possible to calculate the proportion of the total fishing in the lake that was reported by each livery and by the other agencies combined.

The percentage of the total fishing done through the liveries was estimated to be 75% for Kegonsa and 80% for Waubesa. Cottagers and other people gave very little cooperation voluntarily, and because they were numerous and scattered it was impossible to canvass them regularly. Boat liveries varied in cooperation from 0 to 100%. Some livery operators refused to have anything to do with the census; others handed out cards to the fishermen, giving them an opportunity to fill them out if they wished; and a few filled out one card completely for each boat.

Columns 4 of Table 2 are estimates of the numbers of pounds of each fish removed. The average weights on which these estimates are based were obtained, where possible, from measurements of fish caught by anglers in the 2 lakes during the census season. Where such measurements were lacking or insufficient in number, those used by Juday, Livingston, and Pedracine (1937) were employed. Because of limited data, fish from the 2 lakes could not be compared as to size and weight, although there was a tendency for Waubesa crappies and white bass to be slightly longer and heavier than the Kegonsa fish, and for the Kegonsa perch and bluegills to be larger than those from Waubesa.

An estimated 75,000 fish with an aggregate weight of 36,500 pounds were removed from Waubesa, and 45,000 fish weighing 30,000 pounds from Kegonsa. Waubesa yielded 37 fish or 18 pounds per acre and Kegonsa 14.5 fish or 9.5 pounds per acre. These yields compare very favorably with those for some of the smaller lakes in southern Michigan. Hazzard and Eschmeyer (1938) found during 1936 (June 25 to November 30) that 12 lakes in that region with a combined area of about 1,180 acres showed an average of 31.6 fish caught per acre at the rate of 1.2 fish per hour of effort.

The yields of game and pan fish, however, are insignificant in comparison with production of rough fish, especially carp, in the two Wisconsin lakes. In 1936 there was an enormous hatch of carp in lakes of the Madison area. During that year the Conservation Department removed from Waubesa alone a total of more than 7 million small carp an average of 3,570 per acre or 100 pounds per acre. During 1937, the second growing season, 130 carp per acre or 70 pounds per acre were removed by

TABLE 3

TOTAL HOURS AND FISHERMEN, PER ACRE ESTIMATES AND PER DIEM ESTIMATES FOR HOURS AND FISHERMEN

The estimates of total hours and fishermen were obtained by dividing the estimated total number of fish caught by the number of fish caught per hour, and that in turn by the length of the fisherman day.

	Waubesa	*Kegonsa*
Estimated total fishermen	8,490	6,900
Estimated total hours fished	40,320	36,500
Estimated fishermen per acre	4.2	2.2
Estimated hours fished per acre	19.8	11.6
Estimated fishermen per calendar day	55	45
Estimated hours fished per calendar day	260	240
Length fisherman day (hours)	4.75	5.29
Fish caught per fisherman day	8.85	6.55

seining. During 1938 (to December 1) the records show that 2,108,500 pounds of carp—still of the 1936 hatch—were removed from Waubesa, representing 650 fish and 1,040 pounds per acre. Even considering these totals as 3-year production figures, the yearly production for Waubesa over that period would still be 400 pounds per acre or more than 20 times that of game and pan fish. Carp removal in Kegonsa during 1938 amounted to 170 pounds per acre, or about 20 times the game and pan fish removal of the 1938 season.

Some idea of the relative numbers of carp and other fish remaining in the lakes can be gained from estimates made by S. C. Fall, the game warden in charge of the Waubesa seining crew, of the numbers of carp and other fish in each haul made. From October 4 to November 22, 1938, 17 seine hauls were made by this state fishing crew in Lake Waubesa. Each haul averaged 12,900 carp (average weight 1.6 pounds), 5,300 crappies, and 1,800 white bass, with scattered numbers of northern pike, wall-eyed pike, sunfish, black bass, bullheads, suckers, and sturgeon. In some hauls pan fish and game fish were more numerous than the carp; in one haul the carp were 600 times more abundant than the other fish. As many as 15,000 crappies were taken in one haul, and 6,000 white bass, though these maximum numbers of fish were not taken at the same time. One haul, November 23, yielded 254,000 carp with an aggregate weight of 410,000 pounds. In this same haul were an estimated 21,500 game and pan fish. These figures help to show, contrary to what one might expect from the large production figures shown in the 1938 fish census, that the lake is apparently not overfished.

TOTAL HOURS AND NUMBER OF FISHERMEN

(Table 3 and Figure 4)

Nearly 8,500 fishermen used Waubesa and 7,000 used Kegonsa during the period of the census. This means that each day on the average 55 anglers fished in Waubesa and 45 in Kegonsa. The per acre figures, both for hours and fishermen, show that Waubesa was almost twice as heavily fished as Kegonsa. Waubesa fishermen fished a half hour less and caught 2 fish more per fisherman day than the Kegonsa anglers.

Figure 4 showing fishing effort based on the number of recorded hours of fish-

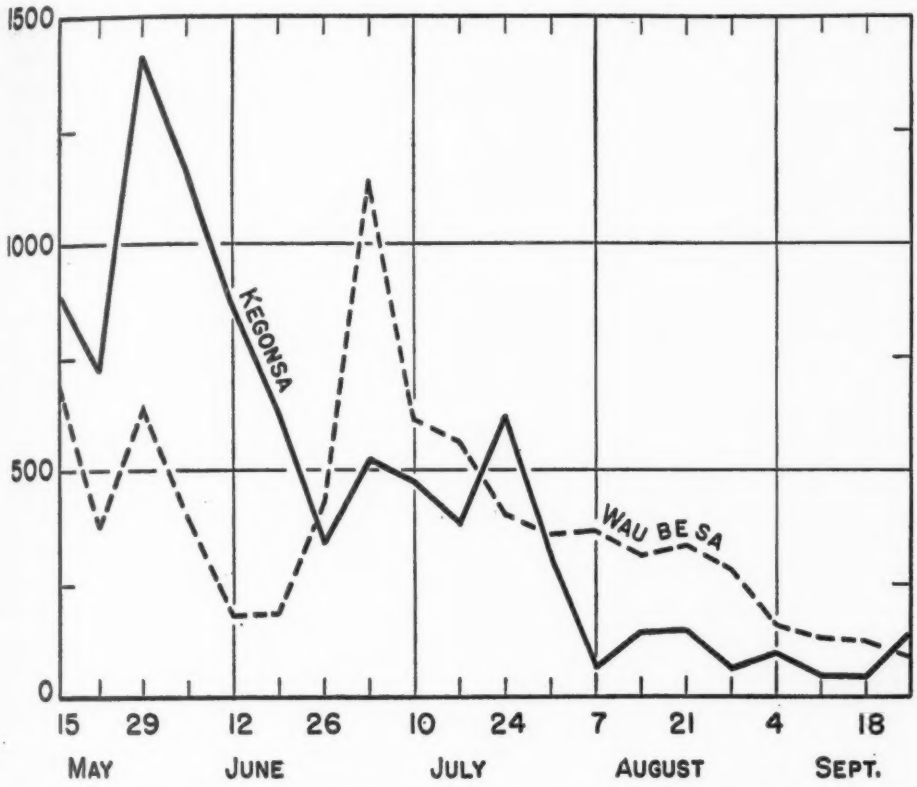

Fig. 4. Weekly fluctuations in total hours of fishing based on data from cards completely filled out. The dates are those for the first day of each week of the fishing season.

ing for each week, demonstrates that most hours were spent fishing in the first half of the season, especially for Kegonsa; and that the lakes were most heavily fished during the opening week and the weeks of Memorial day and July 4th. The length of fisherman day varied from 3.8 to 7.9 hours for Waubesa anglers, and from 4.6 to 6.9 hours for those at Kegonsa. There was a slight tendency for the fisherman day to increase in length with advance of season.

Comparisons with Previous Years
(Figure 3, b and d)

Each of the 2 lakes has had a previous summer fish census taken—Kegonsa during 1936 (Juday and Vike, 1938), and Waubesa during 1937 (Juday, Livingston, and Pedracine, 1937). Comparisons are interesting because of the marked shifts in composition of the catches.

The 1936 Kegonsa census (Fig. 3 d) shows a total of only 7,750 fish compared to 45,260 in 1938, but of these 17.5% were gamefish. In that season white bass instead of making up half of the catch comprised only a quarter, and bluegills were the dominant fish. Crappies represented only 1.4% of the entire catch.

Waubesa (Fig. 3 b) shows an even more striking change from the 1938 census. Instead of crappies comprising 80% of the catch they represented only 11%. Bluegills, perch, and white bass made up much larger proportions of the total than in the 1938 census. Gamefish represented 9.2% of the catch, decidedly more than in 1938. The estimated total number of fish caught was 10,000 smaller than in 1938, which is equivalent to an average decrease of 5 fish per acre.

Shifts of this nature seem to be the rule. In some instances these population shifts are apparently cyclic in nature and are unaffected by stocking policy. Langlois (1939), in discussing records for Lake Rockwell in Ohio, a reservoir for raising bluegills and white crappies, says (p. 18): "in 1937 there were 2 bluegills to 1 crappie; in 1936, 1 bluegill to 1 crappie; in 1935, 1 bluegill to 2 crappies; in 1934, 1 bluegill to 4 crappies; in 1933, 1 bluegill to 15 crappies." In 1931 lacking data showing these trends in relative numbers, it was hoped to have the lake produce more bluegills and 600,000 fingerlings were planted. "This heavy stocking did not influence the trend one iota, the shift in ratios proceeding at an unaccelerated pace exactly comparable to that recorded by Thompson for certain Illinois waters."

STOCKING RECORDS
(Table 4)

With this in mind it is interesting to examine stocking records for Waubesa and Kegonsa obtained from the Wisconsin Conservation Department. Table 4 shows the fish stocked which were legal length at the time of planting or should have reached legal length during the 1938 season. All fry and fingerlings planted during 1937 and 1938 are omitted from the totals because they contributed little or nothing to the number of legal length fish caught during 1938.

From the table it is evident that all species of fish reported in the census

TABLE 4

FISH STOCKED IN LAKES WAUBESA AND KEGONSA DURING THE YEARS 1935–38, WHICH COULD HAVE INFLUENCED THE 1938 FISH CATCH

These records include all adult fish, but only the immature stages stocked in 1935 and 1936, as it is unlikely that fry and fingerlings planted in 1937 and 1938 would have reached legal length during the 1938 season. In 1937 and 1938 fingerlings of bluegills, crappies, sunfish, bullheads, perch, northern pike, and fry of wall-eyed pike were heavily stocked. Large- and small-mouth black bass fingerlings were sparingly stocked.

Species	*Stage of development*	*Waubesa*	*Kegonsa*
Wall-eyed pike	fingerling	5,476,000	5,476,000
	adult	1,320	1,980
Black bass (both species)	fingerling	18,025	16,025
	adult	6,260	3,610
Small-mouth black bass	adult	119	30
Northern pike	fingerling	6,250	6,250
Perch	egg	44,100,000	
	fry	352,000	352,000
	adult	6,320	11,150
Bluegill	adult	9,550	8,770
Crappie	adult	9,250	10,000
Bullhead	adult	500	6,000

have been stocked except rock bass, which occur only in small numbers; carp, which already constitute a problem because of their numbers; sunfish, which were, however, stocked in Kegonsa as fingerlings in 1938; and white bass. All the other species have been planted in the lakes in all stages of development from eggs to adults, the latter often being fish rescued from other lakes or streams. There is not much correlation between fish stocked and fish caught. Anyone hoping to show from the census data in this paper that the fluctuations in numbers of any species caught have been influenced by the stocking policy, must also remember that white bass which were not stocked at all fluctuated almost as widely as any other species.

There is one species stocking may be helping, and that is the wall-eyed pike. The numbers of fish reported in this census are not unusually large, but the fishermen complained of catching too many undersized wall-eyes, estimates running from 15 to 20 times as many undersized as legal length fish. Scale examinations of a good sample revealed that most of the fish were in their second or third growing season. Calculated lengths showed satisfactory growth, which seems to indicate that wall-eyed pike fishing ought to be good during the 1939 season.

SUMMARY

1. This report is based on 2 rather large eutrophic lakes of the Madison region. Complete records of all fish caught were impossible to get, but sufficient data were obtained to make possible a reasonable estimate of the total production.

2. Most fish were caught during the early part of the season with maxima during the weeks of Memorial Day and July 4th.

3. Fishing was noticeably better in Waubesa than in Kegonsa, and the former was fished twice as heavily. Waubesa fishermen fished a half hour less and caught 2 fish more per fisherman day than did the Kegonsa anglers.

4. Fish caught per hour of fishing were 1.24 for Kegonsa and 1.86 for Waubesa, figures that are probably too high because few fishermen turned in cards when fishing was poor.

5. Waubesa excelled in crappie and bluegill fishing, Kegonsa in perch, white bass, and wall-eyed pike. Crappies composed 80% of the catch in Waubesa; white bass totaled 50% of the Kegonsa catch.

6. Waubesa yielded 37 fish or 18 pounds per acre and Kegonsa 14.5 fish per acre with an aggregate weight of 9.5 pounds. There were also removed during 1938, 1,040 pounds of carp per acre from Waubesa and 170 pounds per acre from Kegonsa.

7. Comparisons with a previous census for each lake show a pronounced variation in the composition of the yearly catches indicating that more records are needed for an understanding of these fluctuations.

8. Indications are that wall-eyed pike fishing should be good during 1939 because of the numerous undersized fish present in 1938 that ought to reach legal length during that season.

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THE NEED FOR DATA RELATIVE TO THE OCCURRENCE OF HYDATIDS AND OF *ECHINOCOCCUS GRANULOSUS* IN WILDLIFE[1]

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For many years past, the Federal Bureau of Animal Industry and various Agricultural Experiment Stations have been emphasizing the importance of studies of the animal parasites of domesticated animals. A result was that prior to the stimulus of the hookworm campaigns there was more research being done on parasites of domesticated animals than on those affecting man in the United States. Although long recognized by special students of the subject, only recently has it become generally known that problems of parasitism may be just as acute in wildlife as in domesticated animals and that they are so interrelated that data relative to the parasites of wild animals may throw important light on those of domesticated animals and even on those of man.

An important illustration of this interrelation is afforded by the discovery that in northeastern Minnesota hydatid cysts are commonly present in the lungs of the moose (*Alces americanus*) and that more rarely they are to be found in the white-tailed deer (*Odocoileus virginianus*). This situation was revealed in the course of studies on the diseases of moose conducted by Dr. R. Fenstermacher of the Division of Veterinary Medicine in cooperation with the Division of Entomology and Economic Zoology of the University of Minnesota. The determination of the cysts as those of *Echinococcus granulosus* was confirmed by experimental feeding to dogs and the recovery of typical adult tapeworms of that species. The cysts have been found in the lungs of 11 of 21 moose and of one deer from the same section of northeastern Minnesota where infected moose were first noted.

So far as we have been able to learn there are only two other published records of the finding of hydatids in wild animals in North America. Hadwen (1932), records their presence in a moose taken in 1929 at Le Pas, Manitoba and Law and Kennedy (1933), of the Ontario Government Fur Farm report a heavy infestation of the lungs of an adult moose.

On the other hand they are known to occur occasionally in cattle, sheep, and hogs in the United States. Although recent data are lacking, there is evidence that they are more frequent in hogs in Missouri, Tennessee, Virginia, Louisiana, and Arkansas than in other sections. Magath (1936), reviews 482 known human cases reported for the United States and Canada from 1822 through the first half of 1936. He states that most of the patients were immigrants, but comments, "it is equally clear that persons have acquired the disease who have never been outside either Canada or the United States." He finds that beginning with 1900,

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there have been reported 3 such cases for Canada and 19 for the United States.

The occurrence of hydatid cysts, of course, means that carnivores harbor the adult *Echinococcus granulosus* and scatter the "eggs" (onchospheres), to be picked up by herbivores in grazing, or by man through eating contaminated fruits or salads or, more commonly, from fondling animals. Medical texts and works on human parasitology emphasize the role of the dog as a vector, almost to the exclusion of other possibilities.

The surprising fact is that in spite of all the extensive surveys made, there is only a single authenticated record of a dog harboring the adult worms in this country. Neither is there a record of their occurrence in any wild carnivore except that of the writer (1933), who reported that in the course of the abovementioned work the worms had been found in 2 of 3 timber wolves (*Canis lupus lycaon*) from the same area as the infected moose.

More recently, there has been opportunity to examine five more timber wolves from that district and of these, three contained the tapeworms. Two coyotes (*Canis latrans*) from the area were negative as were also 17 from Lake of the Woods County and Beltrami County, although moose are not uncommon in that more western section of Minnesota. For the opportunity to examine these coyotes we are indebted to Jack Manweiler, of the Soil Conservation Service.

That wild foxes serve as primary hosts in Europe is well established but despite many examinations of these animals for intestinal parasites the worm has never been recorded in a fox in the United States. We have failed to find it in any of 25 red foxes (*Vulpes fulva*) or 25 gray foxes (*Urocyon cinereoargenteus*) from Minnesota. Unfortunately, of these only one, a red fox, was from the known infested area. The other findings may be significant as indicating that the infestation in Minnesota is limited to the so-called "Arrowhead region."

It is precisely because data, regarding even this important parasite, are meager and for wide areas entirely lacking that the writer urges workers to make careful examination of material that comes to hand and to publish their findings.

It should be borne in mind that the larval stages (hydatids) of *Echinococcus* are known to develop in more than 40 different mammals, including various carnivores that may serve also as primary hosts. Of special interest when the possible role of the fox is considered is the fact that hydatids are known to occur in such food species as rabbits, squirrels, and mice. They have even been reported from turkeys and peafowls and though there is at present a tendency to discard these early records, examination of the originals makes it clear that they cannot be summarily dismissed. Such data as are available, especially those of Coutelen (1936), would indicate that if infections do occur in birds, they are very exceptional.

It is certain, however, that the adult worms are much more widely distributed than indicated by present information and this should be borne in mind by workers who have occasion to examine the alimentary canals of carnivores. The worms are minute, rarely exceeding 5 mm. in length and readily

disintegrate in intestines that are not examined while fresh. Due precautions should be taken to avoid infection of the worker, and to destroy the viscera.

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INFECTION OF COTTONTAIL RABBITS BY CYSTICERCUS PISIFORMIS (TAENIA PISIFORMIS)

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The common occurrence of the larval stage (Cysticercus pisiformis) of the dog tapeworm, *Taenia pisiformis,* in cottontail rabbits is well known. In our experience the percentage of infection is from 60% to 75%. In some groups of rabbits examined, almost every animal may be parasitized. The number of cysticerci found varies from three or four upwards to sixty, or even more.

The pathologist dealing with wildlife diseases ordinarily pays little attention to these parasites in the rabbits he examines, as the high percentage of infection of apparently healthy rabbits has led to the conclusion that they are relatively harmless. In the great majority of cases, local pathological changes are not marked. There is little tissue reaction noticeable around the cysts, even those deeply embedded in the liver. When the cysts are attached to the mesenteries, the appearance of the tissue connections indicates little inflammatory reaction by the host, and when they are in the abdominal cavity the peritoneum is scarcely altered.

However, a few cases of infection of cottontail rabbits by these worms have been seen in which it appeared that the parasites were damaging the host to a noticeable extent. All of these were instances in which the number of cysts was very large, ranging up into the hundreds. One hundred and sixty cysts were removed from one animal, and others were present. In heavy infestations, the liver is often virtually studded with cysts. Many cysts lie free in the peritoneal cavity and the perirectal space may be actually packed with them. Some are found in the lungs, and others are attached to the base of the heart, to the large blood vessels, stomach, spleen, mesenteries, or omenta.

When the parasites are present in such excessive numbers, an animal may be visibly in poor condition. Little fat is present in the normal fat depots, such as the mesenteries, subcutaneous tissue, and around the heart and kidneys. The peritoneum may have discolored, roughened areas, and the peritoneal fluid is frequently increased in amount. Instead of being thin and watery as normal, it may be thickened and cloudy. Fibrous changes in the liver capsule and in the mesenteries are occasionally seen. The general appearance of the entrails is suggestive of a chronic low-grade inflammation. The somewhat emaciated condition of the animals suggests an accompanying toxemia. It is doubted that even gross infections are lethal. The harm done is probably that of making the rabbit more susceptible to attacks of other diseases or of predators. It is not believed, however, that these cysticerci are of real importance as a contributing cause of mortality in cottontails. It is conceivable that in the presence of a large and roving population of dogs, such as often characterizes suburban areas, the risk of contracting damaging infections is great. The common practice of hunters allowing dogs to eat the viscera of game accounts in part for the high percentage of infection

among those animals. The ability of dogs to withstand relatively large infestations of the adult tapeworms without marked ill effects, the absence of a public health connection, and the relatively small damage done to rabbits, in light of our present knowledge of this parasite, appear to make control measures unnecessary.

The chief economic loss is wastage of the edible rabbit carcasses discarded by hunters because of the presence of the parasitic cysts in the viscera. The wide publicity given tularemia has made hunters suspicious of all apparent abnormalities, and "spotted livers," what ever the cause, have unpleasant associations in their minds. In cysticercid infestations, the cysts very frequently are embedded in the liver just deep enough to appear as small white spots suggestive of those often seen in tularemia. Probably half of the rabbits shot show some sort of a "white spot" on their livers, and in the vast majority of cases it is a tapeworm cyst. Coccidiosis produces a similar appearance, but the species affecting the liver in rabbits seems to be rare in Michigan. The result is that a great many cottontails are thought unfit to eat when in reality they are edible. Probably an even more important factor than fear of contracting disease is the esthetic objection to eating an animal affected by any sort of disease, even one not transmissible to man.

In Michigan, hunting is an important recreational activity of a large number of people, and opportunities are good for learning what hunters are thinking or doing. Their interest is reflected by the large number of letters requesting information from the Department of Conservation. Each fall a considerable number are received that refer to diseased conditions noticed in rabbits. Specimens also are frequently sent in for diagnosis. Very often the written descriptions are clearly recognizable as referring to cysts of *Taenia pisiformis*. They often enumerate the number of rabbits thrown away because of the "water sacs," "worms," "little white things," etc. found among the viscera.

It would be interesting to know how many pounds of edible rabbit meat are wasted each hunting season because of these harmless parasites—doubtless a vast amount. Our policy in advising hunters has been to warn them against rabbits obviously out of condition or showing other signs of sickness such as sluggishness of movement, but at the same time to allay fears aroused by the finding of parasitic cysts. Frequently one reads advice to hunters and housewives that they wear rubber gloves when cleaning rabbits; and in areas where tularemia is common this is justified. Health authorities at least make their own position safe in issuing such warnings. Human inertia being what it is, however, there is doubt that the instruction is followed by very many people. Rubber gloves are not common in households, nor are they likely to be purchased for this specific purpose.

The records of the Michigan Department of Health and observations of the Game Division indicate that tularemia is a comparatively rare disease in Michigan. About twenty human cases, traceable to Michigan cottontails, have been reported in the years 1936–38. Considering the infectiveness of the disease and the great number of rabbits killed and eaten, the danger appears

slight. In order to play safe, however, it is necessary to explain the possibilities and to put it up to the individual judgment of the hunter to decide what to do with the cottontails he kills.

SUMMARY

One of the most common abnormalities noted in cottontails is infection by the cysticerci of *Taenia pisiformis*. People dislike eating game which they recognize as abnormal. This objection and fear of contracting disease results in considerable wastage of safely edible cottontails. The pathological effect of these parasites on the rabbits seems to be slight. Occasionally massive infestations appear to damage individual animals.

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AGE DETERMINATION IN QUAIL

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In studying a bird species it is often of value to be able to segregate individuals into age groups. Differential behavior of old and young birds and age composition of populations cannot be determined unless age classes can be recognized. This paper describes a method of age determination, dependent on a peculiarity of plumage molt, that seems to hold for at least nine species of American quail.

As used here, the term "age determination" means only the segregation of individuals into three principal age classes—juveniles, young or immature birds in their first year of life, and adults. It is of course easy enough to recognize juvenile quail during the first few months after hatching, but in a winter population there are few differences between immature birds and old. Due, however, to an incompleteness of the postjuvenal or first fall molt, a few juvenal feathers are retained by immature quail throughout the first year of life, and the presence of these serves to differentiate young birds from adults. These feathers are the outer two primaries of each wing and all the greater upper primary coverts.

It was early observed by Dwight (1900) that the postjuvenal molt was incomplete in all quail and grouse. He describes the retention of the outer two juvenal primaries through the first winter, but makes no mention of the characters by which these feathers differ from those of the adult, nor does he speak of the retention of any of the coverts.

Stoddard (1931), in his investigation of the bob-white (*Colinus virginianus*) in Georgia, noticed a difference in the shape of the outer two primaries of old, as contrasted to those of first-year birds, the former being rounded at the tips while the latter are relatively pointed (Plate 13, A, B). He interpreted these pointed primaries of young birds as juvenal feathers held over through the postjuvenal molt, thus substantiating Dwight's observation. On this basis Stoddard separated young birds from old. These characters of "roundness" and "pointedness," however, are subject to considerable variation and intergradation. It is often difficult to place a feather with certainty into one or the other of these categories, particularly when it is badly worn. Still, this method has wide application, and is now generally used for sorting bob-whites into age groups.

Sumner (1935) was the first to point out that in the California quail (*Lophortyx californicus*) not only are the outer two primaries retained through the postjuvenal molt, but the greater upper primary coverts as well. The difference in shape between juvenal and adult primaries is difficult to detect in this species, but the color difference in the coverts is marked. Those of old birds are uniform gray in color, whereas in juvenal and first year birds they are mottled with buff and tipped with white. Sumner states that "Because these mottled coverts are not lost until the second autumn after hatching, they furnish a reliable indication that birds possessing them are not more than one year old."

Van Rossem (1937) also alludes briefly to using this same method for age determination in mountain quail (*Oreortyx picta*). He does not, however, describe the characters of the juvenal and adult coverts.

This problem first came to the attention of the author while hunting bob-whites in Ripley County, Missouri, during the Christmas holidays of 1938. The primary coverts of some 75 birds examined were seen to be of two distinct types, buff-tipped and plain gray, and the buff-tipped coverts seemed to be associated with pointed, the gray with rounded, outer primaries (Plate 13, B, A). The wings of 50 of these birds were saved for further study, for it seemed evident that Sumner's method of recognizing age classes in the California quail might apply equally well to the bob-white. These wings and the skins of 851 American quail of nine species in the Museum of Vertebrate Zoology at Berkeley were subsequently examined in detail.

PRIMARY COVERTS

In every species represented by a fair sample of specimens, some of the apparently mature birds were found to have buff-tipped or mottled coverts. These feathers were definitely established as juvenal by comparison with the coverts of juvenile birds in the collection. In addition, for California, Gambel's, and mountain quail, and bob-white there were available enough specimens in the actual process of molting to work out complete sequences of covert and primary replacement from the juvenile to fully adult stages of life. These sequences were all found to conform to the same pattern. In each case the greater upper primary coverts and outer two primaries of the juvenal plumage are retained through the first winter, and, until lost with the first annual molt, mark a bird as a chick of the previous breeding season. There was every evidence that this pattern of molt occurred in all the nine species represented. Using coloration of coverts to separate immature birds from adults, all available specimens were classified into age groups as shown in Table 1. Birds listed as juveniles still retained in large part their juvenal plumage.

There is a marked similarity between the juvenal coverts of all species listed. In all cases the outer two members of the series, numbers 8 and 9, show the least color differentiation, often being largely gray with merely a buffy fringe on the tip. But numbers 1 to 7 are always marked with buff or rust and distinctly tipped with buffy white. Figure B of the accompanying plate illustrates the juvenal primary coverts of a young bob-white. The coverts of this species are merely margined rather than mottled as in the genus *Lophortyx*.

The adult primary coverts are uniform gray in all species except in the Mearns's quail (*Cyrtonyx montezumae*), in which they are light gray with several large white dots on the anterior edges. The gray coverts of an old bob-white, shown in Figure A, illustrate the appearance of this feather series in adults of all of the species examined save the Mearns's quail.

OUTER PRIMARIES

Stoddard found the juvenal primaries of immature bob-whites sufficiently pointed to be useful in separating these young birds from adults, whose pri-

A (*upper*) Wing of adult bob-white, showing primaries, greater upper primary coverts, and alula. Note rounded tips of outer two primaries, and uniform gray coverts.

B (*lower*) Wing of bob-white in its first year of life. The outer two primaries are relatively pointed, and the greater coverts are marked with buff.

TABLE 1

Species	Juvenile birds all with juvenal coverts	Fully-grown birds		Totals
		with juvenal coverts (young)	with adult coverts (adult)	
Lophortyx californicus	42	224	165	431
Oreortyx picta	56	93	100	249
Lophortyx gambeli	2	62	49	113
Colinus virginianus	1	60	18	79
Callipepla squamata	1	12	5	18
Colinus ridgwayi	1	—	3	4
Cyrtonyx montezumae	1	2	1	4
Lophortyx bensoni	—	1	1	2
Colinus graysoni	—	1	—	1
				901

maries tend to be apically rounded. This difference in shape also is illustrated in the accompanying plate. However, this character has been found less dependable in California and Gambel's quails. An attempt was made to evaluate primary shape as an age marker by checking it against the more reliable color difference found in the coverts. The outer primaries of each bird were listed as pointed, rounded, or too worn to classify before the coverts were examined. Then the covert markings were recorded and the correlations summarized, as in Table 2. Positive correlations were: (1) pointed primaries with juvenal coverts, and (2) rounded primaries with adult coverts. Negative correlations were the opposite combinations. The latter appeared always to result from misjudgment of poorly defined primary shapes.

The results of this tabulation indicate an unquestionable tendency toward pointedness of juvenal primaries and roundness of adult primaries, but the high percentage of negative correlations, particularly in California quail, demonstrates the unreliability of this character as an age index. The higher correlation obtained in the bob-white indicates better defined apical shape in the primaries of this species, and less tendency for intergradation. In all species the shape difference was found to be obscured by wear, hence spring birds were more difficult to classify than specimens taken in the fall. In all, the primary coverts are recommended as a much more dependable index of age than the shape of the primaries, though the latter character may often serve as a useful check.

TABLE 2

Species	Positive correlations	Negative correlations	Unclassified
Lophortyx californicus	79.3%	14.7%	6.0%
Oreortyx picta	78.5%	9.9%	11.6%
Lophortyx gambeli	86.2%	8.1%	5.7%
Colinus virginianus	91.3%	7.8%	.9%

PREMATURE REPLACEMENT OF COVERTS

A small number of birds, which definitely were not in molt, were found to have mixed gray and mottled coverts. Most of these were interpreted as first year birds in which premature replacement of one or several of the juvenal coverts had occurred in the postjuvenal molt. That this can occur is proved by one easily recognizable juvenile California quail (no. 10,511 Mus. Vert. Zool.) which has replaced juvenal coverts 4, 5, and 6 on the right wing, and 3, 4, 5, and 6 on the left wing with adult gray coverts. Table 3 shows the number of birds in each species showing such premature replacement, and the percentage of occurrence. This tendency seems to be most marked in the California and Gambel's quails. In these exceptional cases the coverts prematurely replaced are always median in the series, but not necessarily adjacent. Numbers 6 and 7 are the two most commonly dropped. In no cases were numbers 8 or 9 found to have been dropped, nor was there any evidence that premature molt of this series was ever complete.

TABLE 3

Species	Total number of birds	Specimens showing premature replacement of one or more coverts	Percentage
Lophortyx californicus	431	14	3.2
Oreortyx picta	249	1	.4
Lophortyx gambeli	113	4	3.5
Colinus virginianus	79	1	1.2

FAILURE TO COMPLETE THE FIRST POSTNUPTIAL MOLT

An even more uncommon irregularity of molt appeared in two specimens of California quail in which normal replacement of the juvenal coverts and outer primaries, which normally occurs in the first postnuptial molt, had apparently not been completed. Specimen no. 56,379 (Mus. Vert. Zool.), a male of the race *californica*, collected November 25, 1916, in San Bernardino County, has on each wing a juvenal tenth primary and juvenal primary coverts 8 and 9, all of which are faded and worn, whereas other primaries and coverts are new adult feathers. No sign of molt could be detected. The fact that these juvenal feathers were faded and worn in November is good indication that they had been carried more than a year. A female of the race *achrustera* collected May 9, 1927, in Lower California has very much faded juvenal coverts 8 and 9 on each wing, while other feathers are typically adult and decidedly less faded. This also is interpreted as a case of incomplete annual molt. Such irregularities, however, seem to be very rare.

SUMMARY

1. In most, and probably all, American quail the outer two primaries and the greater upper primary coverts of the juvenal plumage are normally retained through the postjuvenal molt, and are carried through the first year of life.

2. The presence of at least some of

these juvenal coverts, which are either buff-tipped or mottled, is the best means of identifying a quail as a young bird. The plain gray adult coverts are acquired during the first postnuptial molt when the bird is a little more than a year old.

3. Juvenal primaries 9 and 10, also carried through the first year, tend to have pointed tips, whereas the adult primaries tend to have rounded tips. Due to intergradation of shape and obliteration of the difference by wear, this character is a less accurate index of age than the coloration of the coverts.

4. In a small percentage of cases, one or several of the juvenal coverts may be prematurely replaced by adult coverts during the postjuvenal molt. This tendency is most marked in the California and Gambel's quails.

5. Rarely, the distal two juvenal coverts and even the outer primaries may be retained through the first postnuptial molt and into the second year of life. This was observed in only two specimens of the California quail, but conceivably may occur in other species.

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PLANT HISTOLOGY AS AN AID IN SQUIRREL FOOD-HABIT STUDIES

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The usual laboratory procedures employed in identifying the stomach contents of birds and certain mammals have proved to be comparatively unsatisfactory when applied to the finely comminuted material from squirrel stomachs. Resort has previously been made to chemical tests and, on occasion, to starch grain studies, but these and other angles of attack have, in the main, been unsuccessful. For this reason the present study made experimental use of a more refined procedure based on plant histology.

At the outset there were two apparent barriers to success: One was whether diagnostic clues, sufficient to distinguish genera or in some cases species, might be found in small fragments of plant tissue in squirrel food, and second was finding a technique simple and expeditious enough to be practical. Encouraging results were obtained during the analysis of the stomach contents of some seventy fox squirrels collected by the Ohio Wildlife Research Unit and examined in the Washington laboratory of the Section of Food Habits Research. It appears that plant tissues do possess sufficiently distinctive structural characteristics and it was also found that the use of a combination clearing and mounting fluid contributed to rapid and efficient operation. As a consequence, the Biological Survey plans to make further use of this technique in identifications of food items from the stomachs of rodents and possibly ruminants.

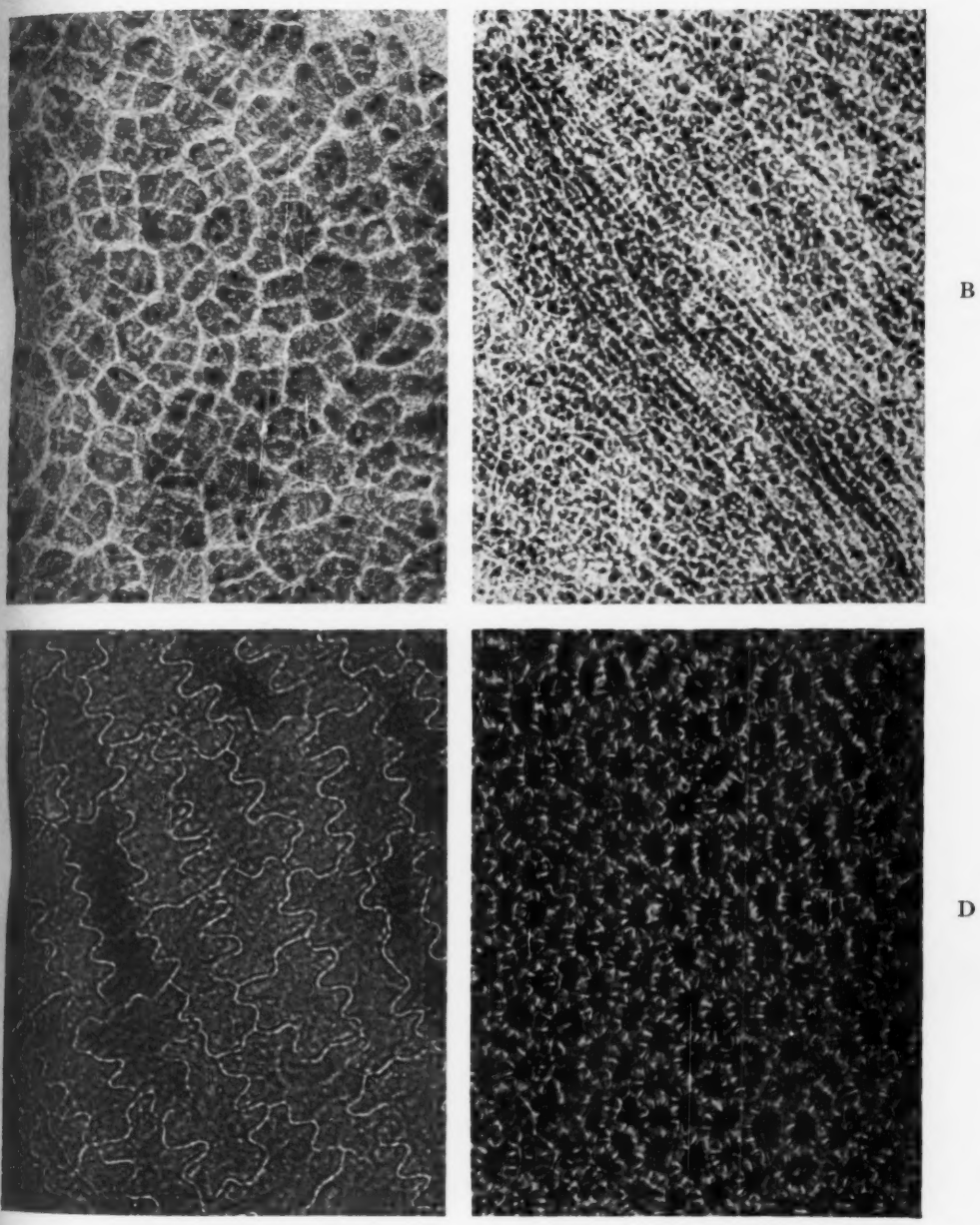
Procedure

It should be realized that in the present demonstration satisfactory results were obtained despite the fact that the writers are not experts in histology. Doubtless superior techniques are, or will be available to yield even better results.

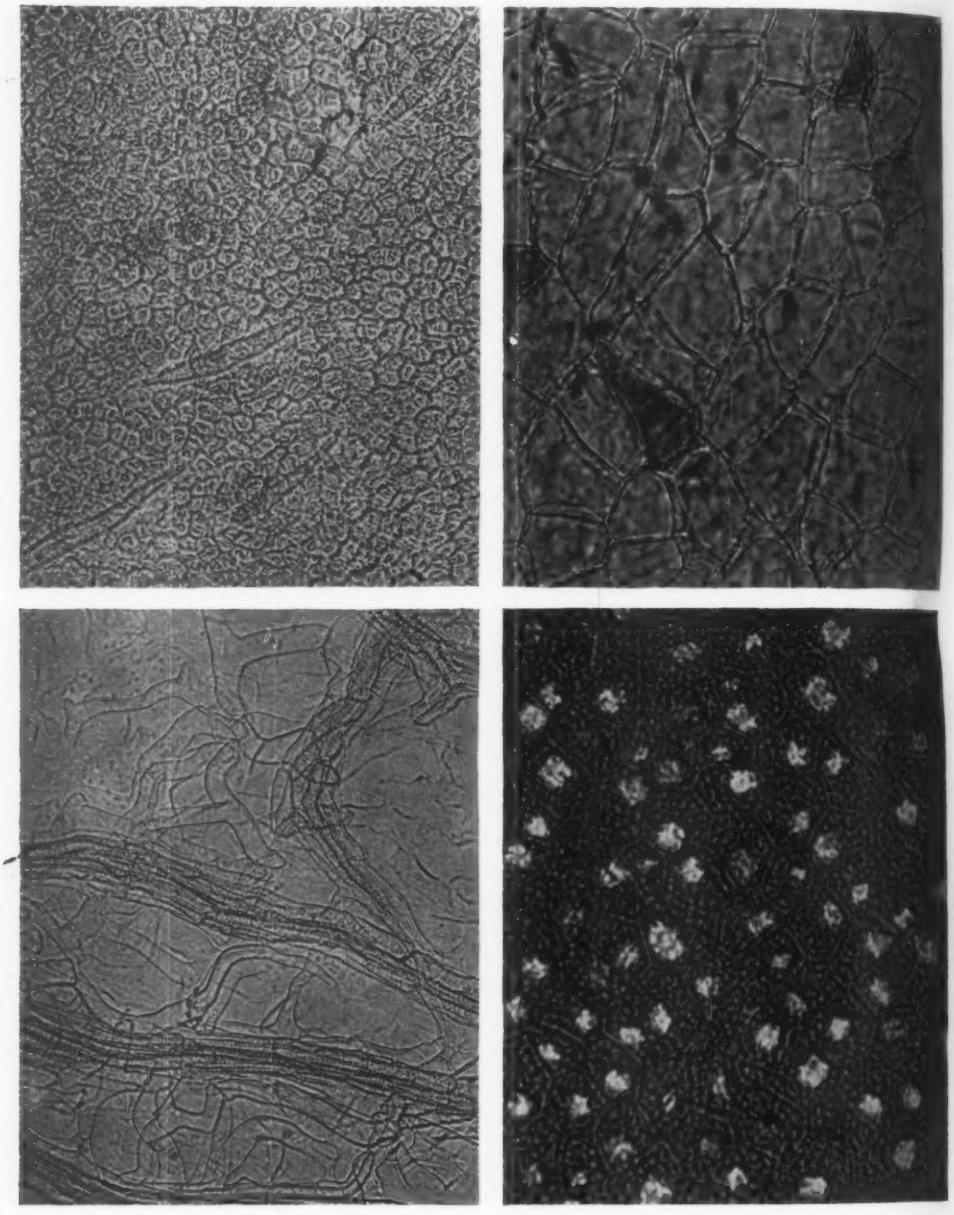
Materials required are for the most part standard equipment in histological routine: a good compound microscope, dissecting kit, slides, cover slips, glycerine jelly, ringing cement, and a Bunsen burner or its equivalent. In addition, however, there is one essential reagent. Hertwig's solution, a combination clearing and mounting fluid. It can be prepared according to the following formula:

19 cc. HCl added to 150 cc. water
60 cc. glycerine
270 gms. chloral hydrate crystals

The method involves two kinds of histological mounts: (1) Permanent reference slides of various plant tissues anticipated in stomachs, and (2) temporary mounts of items from the food material. Permanent slides can be prepared in accordance with directions given in standard reference works on histology such as those of Chamberlain (1), Eames and MacDaniels (2), Winton (3, 4), and Parkinson and Fielding (5), or by the method here described. A collection of reference slides can be made as extensive and elaborate as required, and once it is completed the analysis of stomach contents can pro-



A. "Daughter" or "window" cells in fruit skin of hawthorn (*Crataegus* sp.); ×150.
B. Typical streaked appearance of tissue in testa of pin oak (*Quercus palustris*); ×150.
C. Wavy cell outline in testa of buckwheat (*Fagopyrum esculentum*); ×300.
D. Specialized heavy-walled cells in testa of soy bean (*Soja max*); ×300.

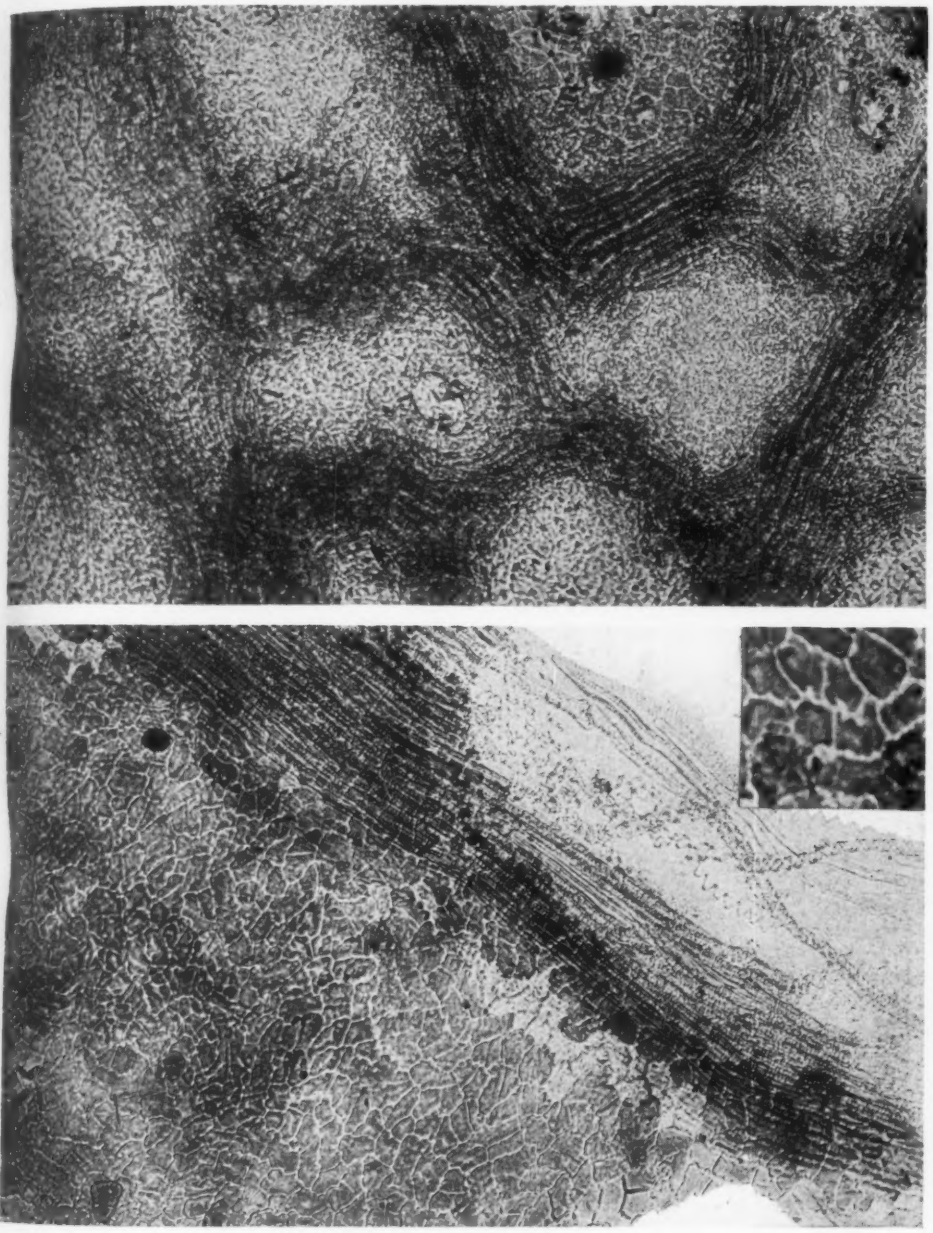


A. T-hairs (attached at the middle of their lower surface) on fruit skin of dogwood (*Cornus* sp.); ×150.

B. Characteristic cell shape and dark areas in testa of beechnut (*Fagus grandifolia*); ×300.

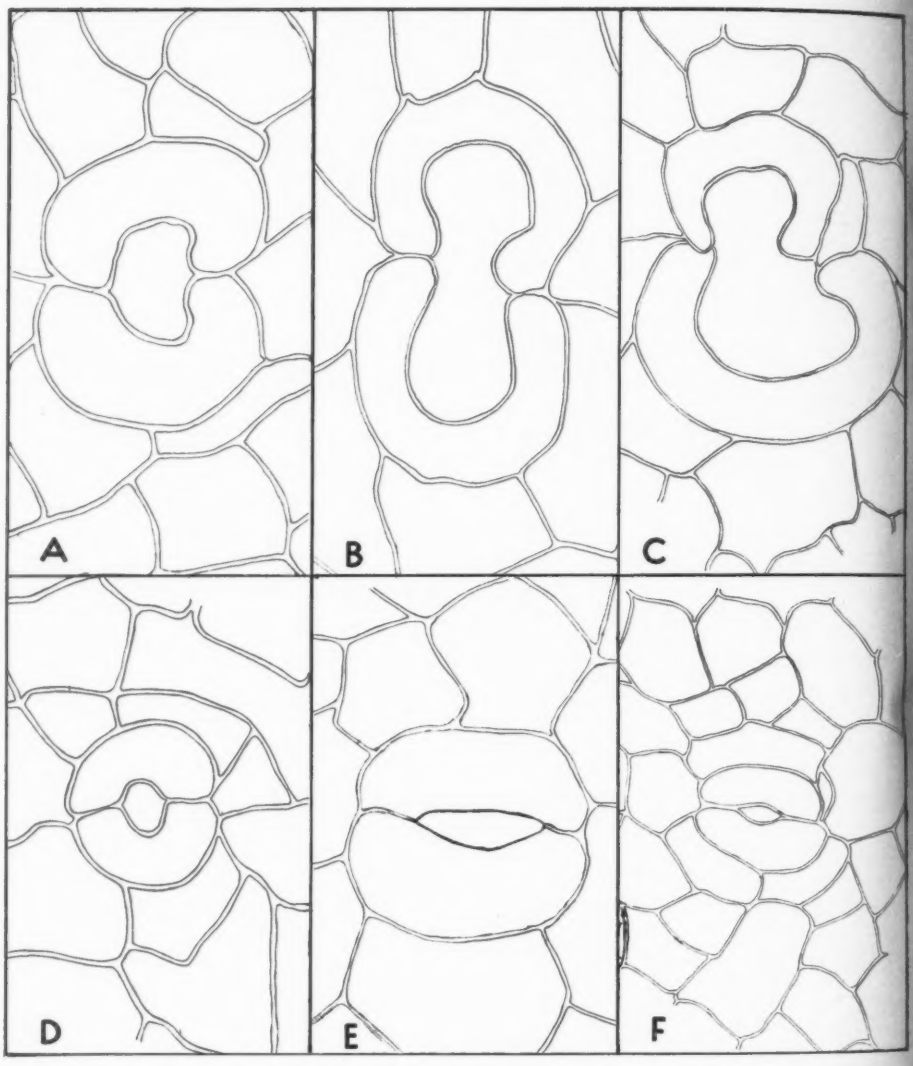
C. Peculiarly shaped cells among vascular strands in wing of pericarp of elm (*Ulmus americana*); ×150.

D. Crystals in cells of that part of the pericarp overlying the seed in elm (*Ulmus americana*); ×400.



A. Closely netted venation in testa of black walnut (*Juglans nigra*); ×150. One of the distinctive stomata is evident in lower center.

B. Characteristic intrusions of cell walls in testa of hazelnut (*Corylus americana*); ×150, (inset ×300). The evident unravelling of spiral vascular elements also is typical.



Examples of the types of stomata found in different species of fox squirrel foods.

A, B, C—Stomata on testa of *Juglans nigra;* D, uniform type of stomata on testa of *Carya alba;* E, stomata on fruit coat of *Prunus serotina;* F, stomata on fruit coat of *Cornus alternifolia.*

Varya
erni-

gress rapidly by the use of easily prepared temporary mounts. This latter phase of operation will be described in some detail.

The stomach material to be identified is first rinsed in water to remove adhering debris and then placed on a slide (epidermis uppermost) and immersed in one or two drops of Hertwig's solution. Next, the slide is held over a flame until the solution comes to a boil. The chloral hydrate and hydrochloric acid in the solution, together with the influence of heat, quickly dissolve the starch and clear the tissue. After the slide is removed from the flame one or more drops of the solution are added. This serves to replace the liquid that has evaporated and also to cool the slide. After the slide has cooled sufficiently, a cover slip is placed over the tissue, which is now ready for examination. The entire procedure usually requires less than five minutes.

Often there may be occasion to save some of the temporary mounts for future study and this can be done without further preparation as the Hertwig's solution contains sufficient glycerine to preserve the material for some time. Permanent slides can be made by replacing the Hertwig's solution with warmed glycerine jelly and then sealing the cover slip with ringing cement. In doing this, extreme care should be exercised to remove (with a damp cloth) all the excess jelly adhering to the slide outside the cover slip, otherwise the seal may not be air tight. For safety two coats of cement are recommended.

A problem encountered in making mounts is keeping the tissue from warping. This difficulty can be alleviated by applying a blotter to the edge of the cover slip and drawing out excess fluid, thereby causing the cover glass to be drawn closer to the slide.

The tendency for the more delicate tissues to curl when heated can be counteracted by preparing the slide with cold Hertwig's solution and then heating only enough to expel air bubbles from beneath the cover glass.

Heavily pigmented tissues, such as the testa of beechnuts or black walnuts, are difficult to study without preliminary removal of the coloring material. These tissues can be successfully cleared by prolonged boiling in Hertwig's solution.

DIAGNOSTIC CHARACTERS

The accompanying figures illustrate a few of the characters available for identification purposes in histological studies of foods. Certain plant tissues require careful study in order to locate details of structure that appear to be distinctive, but more often diagnostic characters are readily observable. Any one feature, such as the size or shape of stomata, the general pattern of cells, structural peculiarities in cell walls, distinctive characters of conductive tissue elements, or specialized forms of pubescence, may be sufficient for identification, but generally it is a combination of several such characters that gives conclusive evidence in determinations. Efficiency in recognition of distinctive structures will naturally depend in a large degree on the sufficiency of reference materials as well as on the breadth of the analyst's acquaintance with histology.

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RELATION BETWEEN TAKE OF UPLAND GAME AND AGRICULTURAL LAND USE IN CONNECTICUT

A. E. Moss

Connecticut has a license system under which the hunter indicates on a stub his take of game for the preceding season at the time he renews his license. These reports are returned to the State Board of Fisheries and Game by the Town Clerks who make out the license. They are not mandatory and results, which are dependent upon the interest the clerks take in their work vary from 0 to nearly 100%. The accuracy of the returns depends upon the individual hunter. No provision is made for indicating the place of kill.

The Biological Survey established a cooperative research unit at the Connecticut State College in 1936 but it was discontinued in July, 1938, due to the withdrawal of the State Board of Fisheries and Game from the agreement.

During its existence, the cooperators obtained a W. P. A. project under which license returns for the years 1927–35 were analyzed statistically and results made available. The town was the unit used and the town records were assembled into county and State totals. The discontinuance of the project terminated this study before analysis in its various phases was completed. The original data were assembled, however, and the reliability of dual samples and other techniques of the statistician were checked. The study, so far as completed, tended toward analysis of the relationship of game and the human factor. This report is as yet unpublished. The above-mentioned statistical analysis brought up the problem as to whether game was a crop and really did have a definite relationship to land as used by the people of this State.

Connecticut is a small State, roughly 100×50 miles, with a population of some 1,500,000 very largely concentrated in 33 towns of over 10,000 inhabitants each. The areas outside the metropolitan districts show a very decided tendency toward specialized or part-time agriculture with owners securing at least part of their income from employment in a city. There is a constant increase of commuters moving from the city to the rural areas for year-long residence and there are no abandoned farms with inhabitable houses. Nevertheless, at the present time it is estimated that about 56% of the State is in forest. The Forestry Department of the Connecticut Agricultural Experiment Station published in its 1915 report the forest area of the State town by town. An unpublished report of 1931 on two counties by the State Forester indicates a slight increase in this area. While the data of 1915 are somewhat out of date, the information is still relatively correct and offers an opportunity to determine whether the take of game has any relationship to land cover.

The resident upland game upon which the sportsmen for the most part depend includes the introduced pheasant, the native ruffed grouse, the gray squirrel, and the cottontail rabbit. This report deals specifically with the pheasant and the grouse.

Fig. 1. Crop land in farms.

The quail was formerly a fairly abundant game bird, state-wide in its distribution. Records do not show excessive hunting or major changes in climatic conditions, nevertheless, this bird has declined in abundance during the past 50 years and has disappeared over much of its range. It is at present fully protected by law and found only in restricted areas.

The major environmental change that has occurred during the past 75 years is in type of land use. Extensive more or less self-sufficient farms have been replaced by intensive highly developed units entirely dependent upon soil types and specialized markets. The area under cultivation has declined from 1,600,000 acres in 1880 to 550,000 acres in 1935 (Fig. 1). The number of farms, however, remains almost stationary at about 30,000.

A further analysis of this change in agricultural pattern brings out a significant fact concerning the all important grain crop. The decline of production of corn for grain and small grains of all kinds is indicated on the accompanying graphs (Figs. 2–3), which show the reduction in total acreage both for the State and per farm. If the current small grain crop were evenly distributed, the total for each farm would be .08 of an acre. This is scarcely a good food strip even if left unharvested. It seems safe to attribute the decline of the quail to the loss of the major portion of its winter food supply.

Hunting pressure forced the game commissioners to restock coverts. This required artificial propagation and the pheasant was the only bird for which breeding stock and rearing methods were readily available. Thus an attempt was made to replace an open land bird, the quail, which has a widely

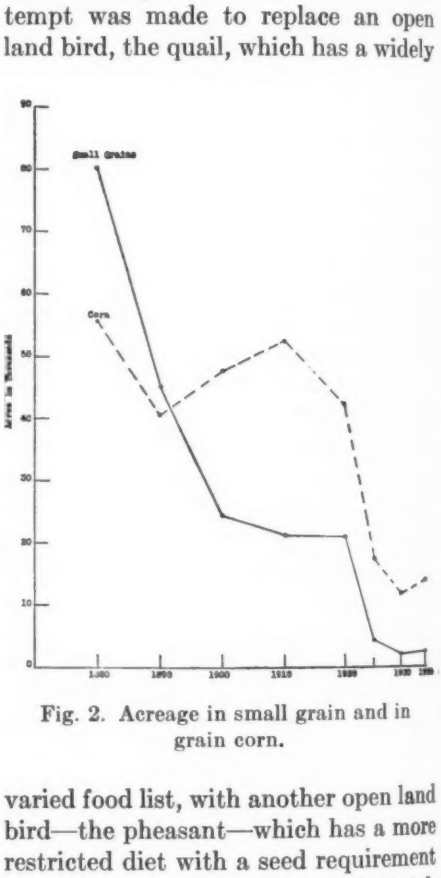

Fig. 2. Acreage in small grain and in grain corn.

varied food list, with another open land bird—the pheasant—which has a more restricted diet with a seed requirement of well over 85% of the yearly total. The amount of seed necessary to success is not produced by the type of

agriculture practiced in the State at the present time.

The State Board of Fisheries and Game first introduced the pheasants in 1908 and since then has liberated some 300,000. The earlier releases were handled by alloting a certain number of birds to each game club or other interested local organization. Later, the work was taken over by the warden force. Information as to location of liberations, even to the town, is very indefinite up to 1928. Since that date, the department has records by towns, and since 1936 by specific locations within towns. In general, the state-wide method of liberation has changed but slightly. Since 1936, however, an attempt has been made to stock only suitable habitats and with a sex ratio that seemed best for the locality. The density of stocking as indicated by liberations is not easy to determine as the only unit available is the town, and the towns are not uniform in size or in character of cover. The pheasant is an open land bird; therefore, the unit adopted in this analysis was acres of open land.

The total liberations per town since 1928 were made available through the courtesy of the State Board of Fisheries and Game. While this information does not cover the same years as the statistical analysis of the hunting records, it probably is a representative sample of the preceding 15 years. The density of stocking as represented in Figure 4 is acres of open land of the town divided by the total birds liberated over the ten-year period 1928–38 and is, therefore, acres per bird. The figures are for stocking only and do not take into consideration natural regeneration but represent the distribution by which the State is attempting to maintain and improve the pheasant take in the different towns.

As the liberations are state-wide and have been over a period of 25 years, it would seem safe to assume that there has been sufficient time for the environ-

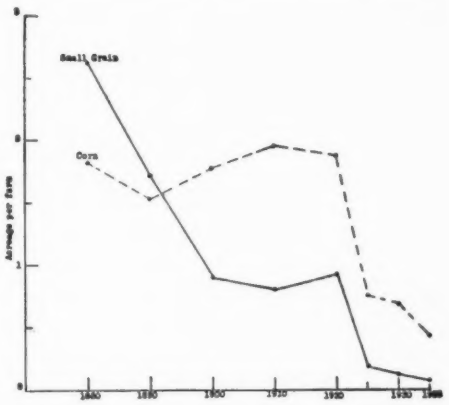

Fig. 3. Average acreage per farm for small grain and for grain corn.

ment to have made itself felt. The first attempt to check this theory assumed that the pheasant was more closely associated with open lands and the grouse with woodlands. The data from the above-mentioned unpublished report were assembled and an attempt was made to establish the relation, if any, of the total reported kill of pheasants in any town to the amount of open land. This ratio was derived by dividing the acres of open land by the total kill reported and represents the recorded yield for this 9-year period expressed in terms of acres per head of game. Corresponding figures were obtained for the ruffed grouse, gray squirrel, and cottontail rabbit but, in these cases, the kill was related to the forested area. See Table 1.

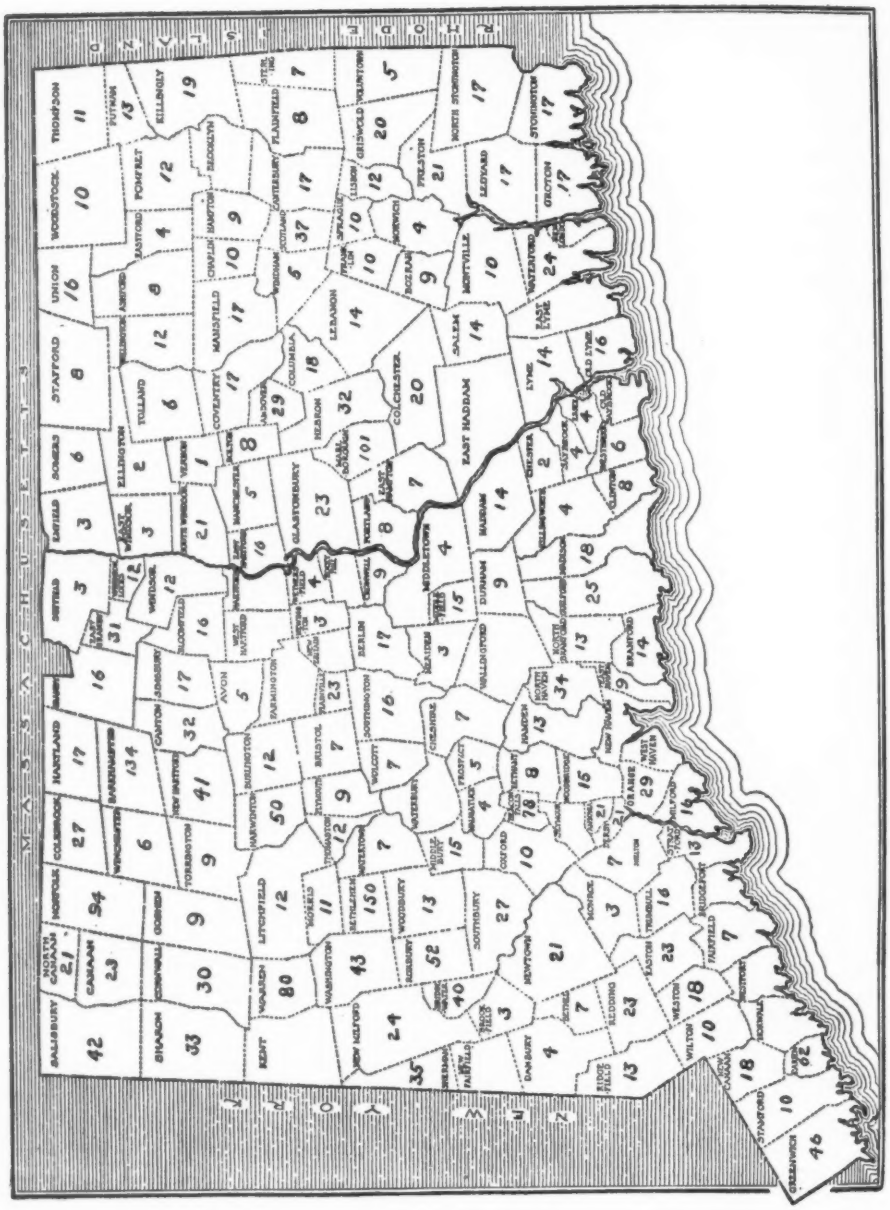

Fig. 4. Acres of open land per pheasant liberated 1928–1938.

TABLE 1
RELATION OF THE KILL OF UPLAND GAME TO OPEN AND FORESTED LANDS
1927–1935

Per cent of forest by towns	Acres of open land per pheasant killed	Acres of forest land per animal killed		
		Grouse	Squirrel	Rabbit
0–20	7.5	8.1	1.3	1.8
21–30	11.0	10.9	4.6	3.0
31–40	19.6	24.9	8.9	10.2
41–50	23.1	21.9	9.2	13.4
51–60	36.9	34.1	12.9	20.1
61–70	18.5	32.5	11.3	16.9
71–80	26.9	36.9	28.1	20.5
81–	64.9	96.6	47.2	49.9

The averages seem to indicate that there is a correlation between acreage of open land and numbers of pheasants up to the 51–60% class, above which there appears to be some unknown factor entering into the equation. The grouse-cover relationship also appears to be somewhat irregular.

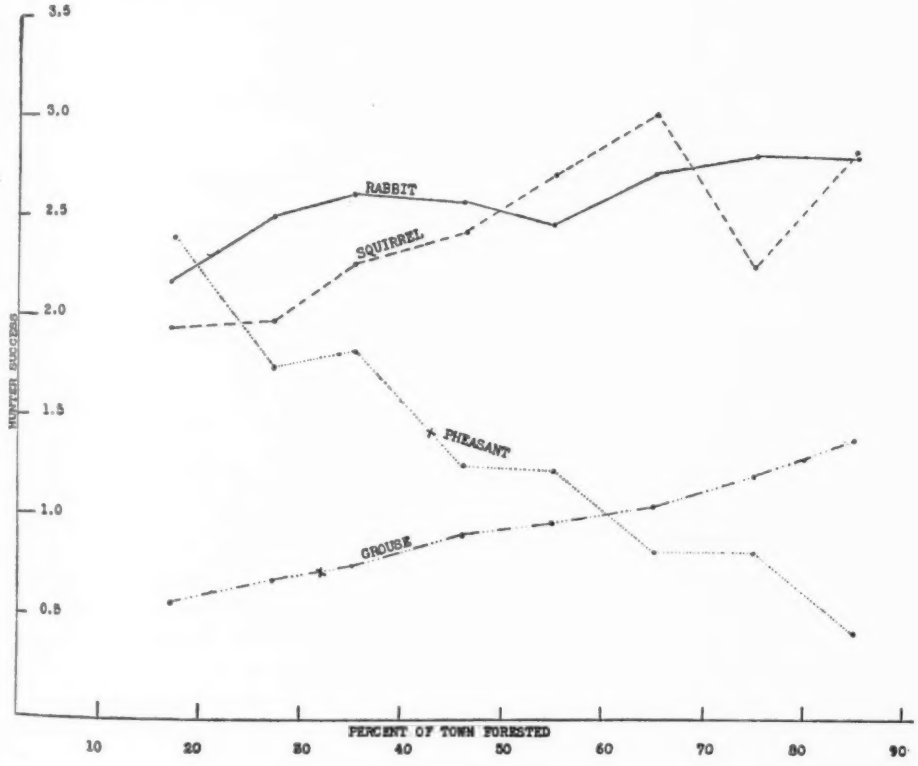

Figure 5

Fig. 4. Acres of open land per pheasant liberated 1928–1938.

The figures for the pheasant kill show 2.8 as the least acreage per bird while the greatest is 161 acres. Those for the grouse kill vary from 2.1 to 159 acres per bird. As this approach did not give

Hunters with ample time will hunt wherever game conditions seem to offer the greater possibilities for success. There are, however, a considerable proportion of the hunters who find the time

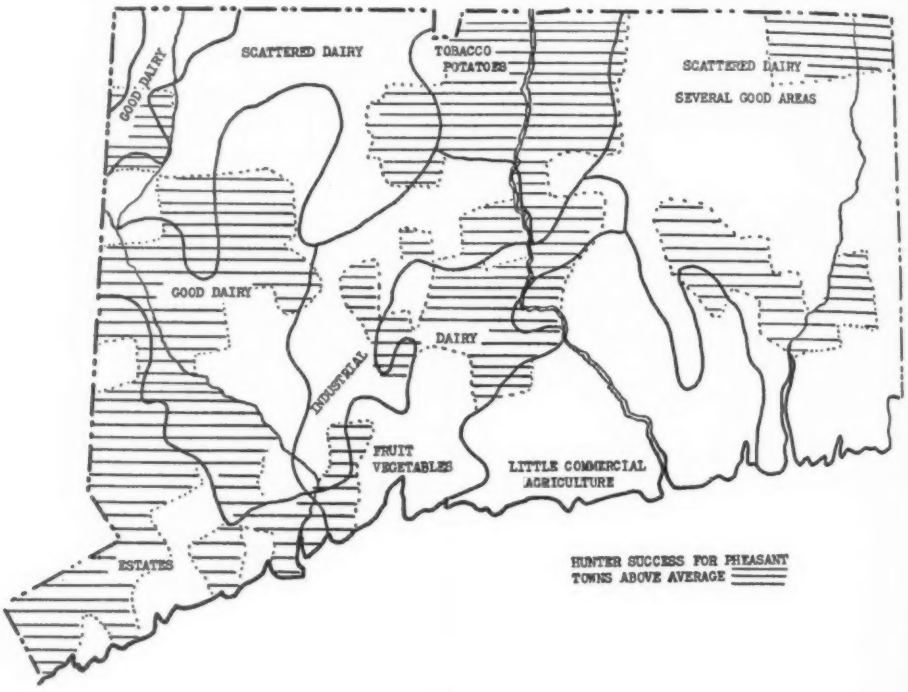

Figure 6

very good results except to indicate that there might be a relationship if it could be interpreted, an attempt was made to use hunter success as an index. The success of the average hunter in Connecticut was determined by dividing the total kill reported for each upland game species by the number of hunters reporting. These figures (accumulative averages for the nine-year period 1927–1935) show the hunter success or efficiency as being 1.43 pheasants, 0.74 grouse, 2.19 squirrels, and 2.66 cottontail rabbits.

available so limited as to make impossible the hunting of cover other than that near their residences. There are no data available to verify this hypothesis but in the lack of negative evidence it is assumed that hunter reports give a fair sample of the abundance of game within short travel distances. This is supported by findings developed later.

The towns were again grouped by percentage of forest area but the comparison factor was the hunter success in each town as represented by the total reported kill divided by the number of

hunters reporting. For the purpose of this article, all cities were eliminated and also certain other towns where the returns of license stubs were not sufficient to give reliable data. The following graph (Fig. 5) shows these data averaged according to the forested percentiles.

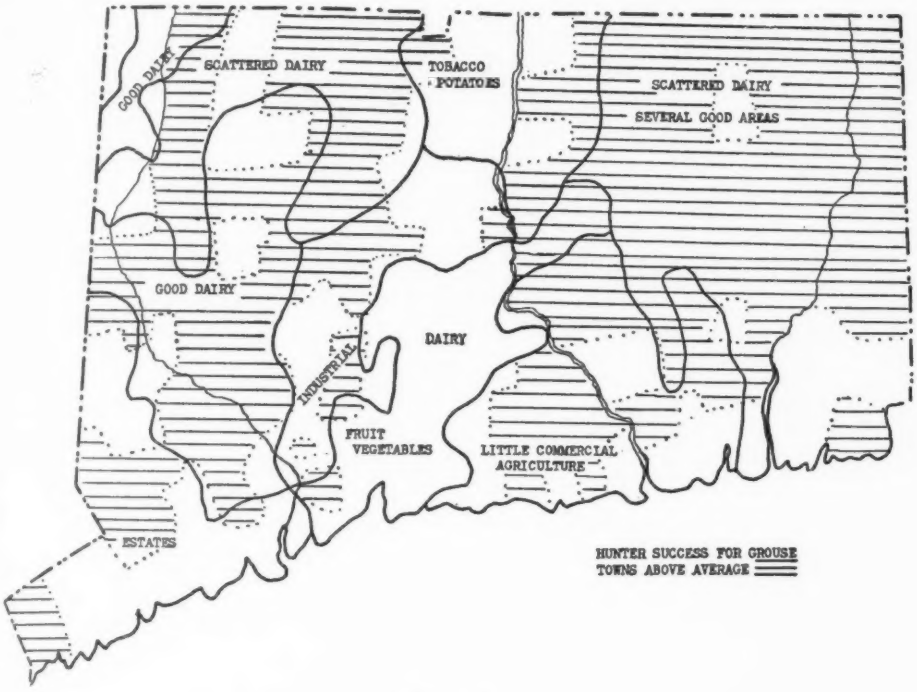

Figure 7

This treatment of the data evidently has eliminated much of the erratic character of the acre factor. The relationship of hunter success to forested cover is quite evident for the birds and is fairly well defined for the rabbit but not as well for the squirrel.

A question presented is: Do agricultural use and soil productivity have an influence upon game bird crops? The Agricultural Economics Department of Connecticut State College has made an intensive study of the agriculture of the State. The information pertaining to land use or land productivity here used has been gleaned from published or unpublished reports available in their offices.

A map is available that shows the major land use patterns and their relative productivity. The towns of the State were classified as either above or below average in hunter success for pheasants and were plotted upon this map (Fig. 6).

It is clear that the towns above average in take of pheasants follow closely the agricultural pattern, coinciding with areas where agricultural success is high. However, there appears to be

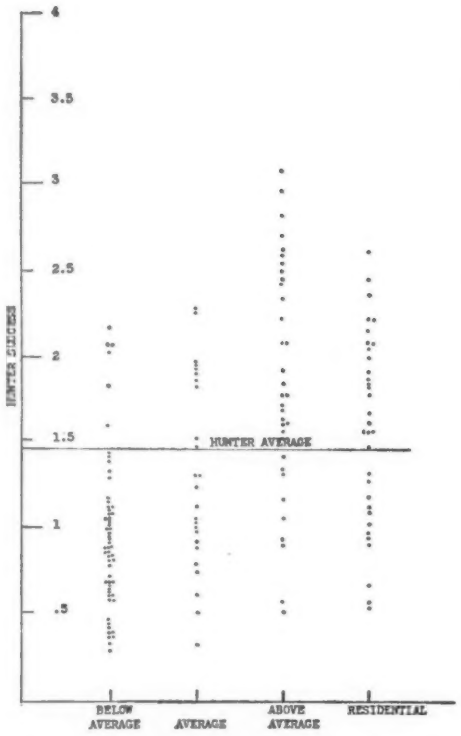

Fig. 8. Hunter success in take of pheasants by towns arranged according to soil productivity.

some influence in the "estate" area that does not necessarily follow land use and may possibly be a leisure time factor.

The take of grouse was plotted in a similar manner (Fig. 7) and it also follows the land use pattern but with an inverse correlation compared to the pheasant bag. Again, the influence of residential use of land appears as a factor, modifying the take in relation to agricultural land utilization.

As a check, the agriculture-game relationship was again approached from a different angle. The soil productivity of the towns was classified by one of the best informed men on the College staff into below average, average, or above average classes. Towns which were very largely residential were placed in a separate list. The hunter success of the towns was then recorded in the form of a scatter graph (Fig. 8). Again, the take of pheasants very closely follows soil productivity while that of grouse (Fig. 9) is in inverse ratio. The residential town places at about the state average for both pheasants and for grouse. Open hunting areas rapidly disappear with increased residential use of land and such towns are not "average" in the soil-productivity classification. The take of game however, corresponds to

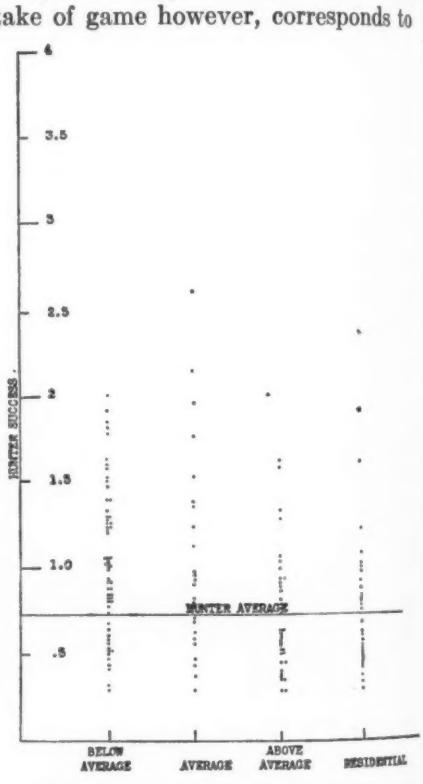

Fig. 9. Hunter success in take of grouse by towns arranged according to soil productivity.

the "average" for the entire State. This would seem to indicate that hunters of the residential towns travel extensively enough to sample the State whereas in the rural towns, the hunters do not have to travel to find hunting and, therefore, give a truer sample of local conditions. Possibly a study of the success of hunters of residential regions may be a rapid method of getting an index of average game conditions.

The possibility of the method of pheasant liberations influencing distribution of the birds was again checked by grouping the towns on the soil productivity basis and plotting the ratio of liberations in the form of a scatter graph (Fig. 10). This shows the rate to be relatively uniform irrespective of the agricultural factor.

This analysis of the available data seems to indicate clearly that the pheasant is dependent upon agriculture for its food supply and that the pheasant harvest is directly related to soil productivity. Study of present agriculture seems to indicate a lack of crops that produce suitable food for pheasants, especially during the winter.

On the other hand, the ruffed grouse appears to be independent of the agricultural pattern, and its population is more nearly correlated with natural cover. As yet, we have no method of evaluating grouse food and cover in terms of soil productivity as recognized by the agronomist.

All of the data here used were collected with the town as the unit, as was unavoidable under present conditions. The town boundaries do not normally follow physiographic features, and, least of all, soil types. All vegetation, however, and agriculture, with its evi-

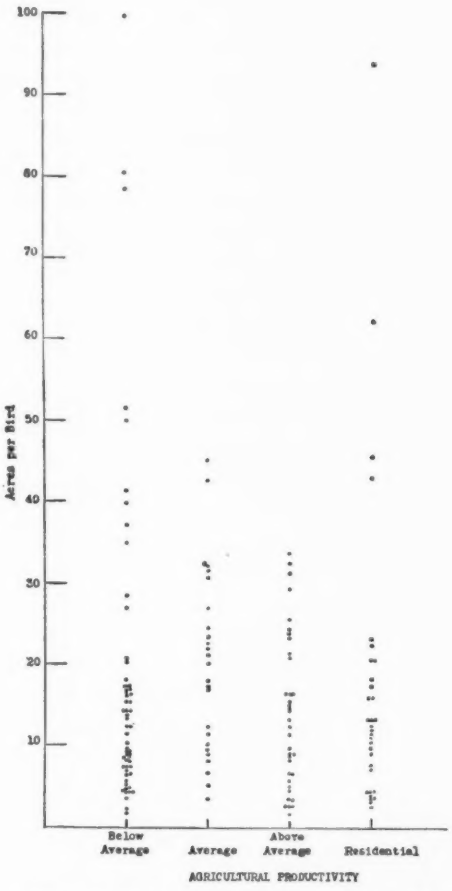

Fig. 10. Pheasant liberations 1928–38 by towns arranged according to agricultural production.

dent influence on pheasant production, do follow soil types.

As to future work, it may be ventured that while it will doubtless be impracticable to collect statistical data other than by town units, vegetational data and corresponding wild life production should be by major soil types as far as possible.

In a State having as diversified conditions brought about by the physiography and human developments

which so definitely follow land conditions, game management might well be based on a long-time plan in which an attempt should be made to evaluate both present and future trends in land use.

Game birds react to their habitat and a permanently satisfactory habitat is essential to stable production. In Connecticut, that condition must be built up and the process will take a period of years. Useful information is accumulating on land use trends that have been under study by numerous agencies both public and private for many years. Hunting, no doubt, will maintain its present status or even increase in importance. The policy of providing the "game" should be based upon a long time plan in which land use trends, relative costs in terms of birds produced, and the place of public ownership receive due consideration.

This study seems to indicate that the success of pheasant stocking in this State is very closely related to the average productivity of the soil. Increase of pheasants on the less productive soils can be brought about only by land management practices that will improve food and other habitat conditions.

The findings also indicate the possibility of sampling regional hunting conditions through the study of the success of hunters from residential areas.

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OBITUARIES

Stuart Taylor Danforth[1] was born in Jersey City, N. J. on September 23, 1900, and he died at home in West Boylston, on November 25, 1938 of pulmonary tuberculosis. He was buried in Jaffrey, New Hampshire in sight of Mt. Monadnock, which he had loved since boyhood days.

He had been in frail health ever since he suffered a severe case of pneumonia while at Cornell in 1925, but his great courage and indomitable will resulted in unusual accomplishment during the intervening years, during which he published over fifty papers, mostly on the birds of the West Indies.

When he was a very young boy, Stuart gave evidence of a remarkable and telling interest in birds. In this he was guided at first by his father, who was also a born naturalist, and by the time he was seven years old he was keeping voluminous notes on his bird observations, much of the time without even the knowledge of his parents.

His first formal school life began when he was thirteen, when he entered the high school in East Jaffrey, New Hampshire.

In 1917 he entered Rutgers College in New Brunswick, New Jersey, where he specialized in Entomology, and graduated in 1921.

The next winter, his family having moved to Mayaguez, where his father was Professor of Zoology in the College of Agriculture and Mechanic Arts of the University of Puerto Rico, Stuart accepted a position to teach English in the High School in that City.

The following year he entered the Graduate School of Cornell University, specializing in Ornithology, Entomology, and Physical Geography, and there he acquitted himself most creditably, receiving his Ph.D. in 1925. The following year he taught Zoology in Temple University, Philadelphia, and the next year he was called to the College of Agriculture and Mechanic Arts in Mayaguez, to succeed his father. In 1933 he was made Head of the Department of Zoology.

He attended most faithfully to his work in the College and did much to aid and inspire his students if they showed real interest in their work, but he had little patience with carelessness, or an attitude of indifference or wavering honesty. He was tireless in his efforts to raise and keep the academic standards of the College on a high level.

His vacations were spent in visiting the various Islands of the West Indies in pursuit of his bird studies, or in coming to the States, where much of his time was passed at the Field Museum, in Chicago, and at the National Museum in Washington, as well as in other institutions, working out the problems which arose from his collecting trips.

He was granted sabbatical leave from the College for the second semester of 1937, and spent the time from early January until the middle of August traveling among some of the smaller and less known islands of the West Indies. The results of his observations

[1] Obituaries of Danforth also have appeared in *The Journal of Agriculture of the University of Puerto Rico*, 23(1), January 1939, pp. 1–8 (portrait); in *Science*, 89(2304), February 24, 1939, pp. 169–170; and in *The Auk*, 56(3), July, 1939, p. 362.—EDITOR

during that expedition have not yet been fully published, although he completed one paper while confined to bed in his last illness.

In 1933 his achievements were recognized by election to membership in the American Ornithologists' Union.

His collection of bird-skins, numbering about 3,000, was given to the U. S. National Museum, and one of beetles was presented to the Museum of Comparative Zoology at Harvard.

The unfinished results of his last expedition will probably be written up at a later time by Dr. Alexander Wetmore, of the National Museum, who has his notes.

The last months of his illness, when he knew the end of his life was approaching, were marked by calm fortitude, by earnest effort to assure that his work should be carried on, and by a faith and confidence in his own future life. These abiding qualities have left precious memories with his mother and his numerous friends.—ARTHUR A. ALLEN.

George Charles Embody[1] was born in Auburn, N. Y., November 23, 1876, and died of a heart attack at his winter home in Daytona Beach, Florida, February 17, 1939. He was educated at Colgate University (Madison, N. Y.) where he took the B.S. degree in 1900 and the M.S. in 1901. While there he wrote an account of the "Birds of Madison County." He was known as a quiet, versatile scholar. A score of years later his Alma Mater awarded the honorary doctor's degree to their former star athlete and assistant in physics. He taught at Delaware Literary Institute, Bradford High School, and Bethel College. He then, 1906–1907, attended Johns Hopkins University and was there a year before its greatest zoological teacher, William Keith Brooks, died. For a year Embody taught at Randolph-Macon and then came to Cornell in 1908 to take his Ph.D. degree which he obtained in 1910. Before that period his investigations and publications largely pertained to birds and crustaceans, though he had always been an ardent fisherman. Beginning in 1908 he started his active ichthyological studies, the subject of his thesis being the pike and pickerel of the Renwick marshes. In 1909, during Professor H. D. Reed's absence in Germany, Dr. Embody was made an assistant in vertebrate zoology to help in teaching. Thereafter except for one year at Butler 1910–1911, he continuously served at Cornell. In 1911–1912 Professor Needham engaged him as an instructor in aquiculture; and he taught that subject, fish culture, and limnology there for 28 continuous years except for a short period at the Fisheries College of the University of Washington.

Embody was dean of the teachers of fish culture in the United States and Canada and was revered by students and laymen alike. The American Fisheries Society long ago honored him with its presidency and many a State Fish or Conservation Commission or private agency sought his counsel.

As a teacher, we knew him intimately in 1908–1910 and no one ever was a more agreeable colleague.

The Cornell Departments of Entomology and Zoology mourn a genial,

[1] The principal facts in Embody's career are recorded in *American Wildlife*, 28(2), March-April, 1939, p. 63.—EDITOR

cooperative, high-standard associate. The professionals in fish culture lose an ornament in their field and the laymen in fisheries an outstanding kindly leader. His students and friends admire, respect, and hold in affection his memory and counsel.—ALBERT HAZEN WRIGHT.

Carlos Clyde Goff, Assistant Entomologist of the Florida Experiment Station, died at Gainesville, Fla., on January 13, 1939 of coronary thrombosis. He was born October 2, 1905, at Charleston, Ill. He specialized in plant and animal ecology at the Eastern Illinois Teacher's College and at the University of Illinois. From 1927 to 1930 he was Assistant Entomologist with the Illinois State Natural History Survey. In 1930 he joined the staff of the Florida Experiment Station, on which he continued until his death, except for a year's leave spent at the University of Michigan completing the preliminary requirements for the Ph.D. degree.

Mr. Goff's wide interests were shown by his contributions in the fields of mammalogy, herpetology, entomology, and animal ecology. He was a particularly gifted field investigator. His earlier studies in Florida were on the vertebrate pests of the state crops. More recently he had been occupied by studies of the life-history and habits of *Geomys* and of the commensals inhabiting *Geomys* and *Gopherus* burrows.

The Florida Experiment Station regrets the loss of an associate whose broad interests and enthusiasm contributed much to the work of the organization, and promised more for the future. Mr. Goff's quiet friendliness, his kindly wit and his unfailing good humor endeared him to all who knew him, and he will be keenly missed by his many friends.—LAURA C. HUBBS.

EMPLOYMENT SERVICE OF THE WILDLIFE SOCIETY

Purpose: This service will be operated as a department of the Journal for the dual purpose of publishing information concerning (1), available positions and (2), qualifications of persons seeking such positions.

Limitations: To conserve the time of officers, the Employment Service will be confined to announcements of openings and statements of the qualifications of candidates. All correspondence will be between prospective employers and applicants, and not with officers of the Society. Appointments to nearly all federal and many state positions in wildlife management are based upon Civil Service ratings. Aspirants should therefore apply to the U. S. Civil Service Commission, Washington, D. C., or to corresponding state organizations for announcements of examinations. Appointing officers are invited to report vacancies and new positions to the Employment Service.

Procedure: Each member will be entitled to one five-line statement of his education, qualifications, and preferences as to type of position in each volume. Additional lines will be charged for at the rate of 5 cents per line, and additional insertions at the same rate for all lines required.

All communications for the Employment Service should be sent to the Editor, W. L. McAtee, Bureau of Biological Survey, U. S. Dept. of Agriculture, Washington, D. C.

Larson, Keith D., 345 West 6th St., St. Paul, Minn. B.S. Hamline University 1934, major, biology; minor, chemistry. Finishing M.S. University of Minnesota this summer (1939), major, zoology; minor, forestry. Four years' experience in conservation work, consisting of two years in forestry, and two years in lake and stream survey studies. Employment desired in a conservation program.

Mathiak, Harold A., 3808 N. 13th St., Milwaukee, Wis. B.S.F., M.F. University of Michigan, 1938. Major wildlife research, minor forestry. Position desired in wildlife research.